The methane footprint of nations: Evidence from global panel data *

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Abstract

We develop a unique global dataset on methane inventories derived from production, final production, and consumption for 1997–2011. Anthropogenic emissions are quantitatively important for global warming and have increased about 25% from 1997–2011. We analyze the drivers of methane emissions per capita, both economy-wide and across sectors, paying attention to the form of the relation between emissions and growth. There is relative decoupling between methane and growth, and the relationship is non-linear. The effect of economic growth on emissions is likely to worsen when moving from lower to middle levels of development, and only improves as countries reach high levels of income. There is substantial heterogeneity in this relationship at a sectoral level, and sectoral transformation accompanying economic growth also leads to increased emissions. Together, relative decoupling and sectoral diversity challenge the design and implementation of environmental instruments to mitigate methane emissions. Methane also poses challenges to the overall management of greenhouse gas levels.

Keywords: Economic growth, methane emissions, MRIO analysis, production-based inventories, methane footprint, income-elasticity, threshold estimation, sectoral analysis.

JEL-codes: F18, F64, O44, Q54, Q56.

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1 Introduction

Methane (CH_4) is one of the most important greenhouse gases (GHGs). Anthropogenic methane emissions are responsible for about 20% of the warming induced by long-lived GHGs since pre-industrial times, making it the second largest contributor to climate radiative forcing after Carbon Dioxide (CO_2; EPA, 2012). Methane has significant warming potential, notably in the beginning of its atmospheric life, and there is evidence of a strong and mostly coincident linkage between methane emissions and global temperature trends (Estrada et al., 2013).

Atmospheric methane concentrations result from a mix of natural and anthropogenic sources.[1] Methane concentrations from anthropogenic sources experienced an exponential increase in the late 1970s and sustained growth in the 1980s, followed by a slowdown during the 1990s and a general stabilization from 1999 until 2006. Since 2006 atmospheric methane levels have started to rise again (Kirschke et al., 2013). Estrada et al. (2013) identify two main causes of the slow-down in warming since the mid-1990s, which highlight the impact of human behavior in global warming. The first is the reduction in chlorofluorocarbon (CFC) emissions as a result of the Montreal Protocol (1989). The second is lower anthropogenic methane emissions, possibly caused by a decrease in microbial sources resulting from the use of chemical fertilizers and more efficient water use for rice production in Asia.

Despite its importance, methane has neither been a primary focus in recent economic and political debate on greenhouse gas regulation, nor has it been among the main targets of environmental policies. National methane regulations exist in some countries, but international cooperation in the reduction of methane is largely missing. While the Kyoto Protocol (1997) was meant to limit emissions of CO_2 and five other GHGs including methane (measured in CO_2 equivalents), binding emission reduction targets are small and confined to Annex I members of the protocol[2] (i.e. developed economies), providing substantial room for emission leakage. Furthermore, the protocol has not introduced mechanisms to change the behavior of the countries bound by emission targets of its Annex I (Barret, 2008), while the enforcement of compliance with these targets has also been problematic

[1] Kirschke et al. (2013) group sources of CH_4 emissions into two natural sources (natural wetland and other natural emissions) and three anthropogenic sources (agriculture and waste, fossil fuels, and biomass and biofuel burning). During the 2000-2009 period, natural wetland emissions and agriculture and waste emissions were the main sources of methane emissions, followed by anthropogenic fossil fuel emissions, other natural emissions, and emissions from biomass and biofuel burning.

[2] The Annex I countries were originally defined by the United Nations Framework Convention on Climate Change (UNFCCC). In the Kyoto Protocol emission targets for the Annex I countries were determined, with the exception of Turkey, and enshrined in the Annex B of the protocol. For the rest of the paper we stick to the term Annex I countries.

(see Nentjes and Klaassen, 2004, Hagem et al., 2005, Feaver and Durrant, 2008, Aichele and Felbermayr, 2012).

Compared to the extensive economic literature on CO_2 emissions, the literature analyzing the socio-economic factors driving methane emissions is relatively scarce. The approach has largely been cross-sectional (Burns et al., 1997, Rosa et al., 2004, Jorgenson, 2006), leaving room to omitted variable bias, or has only covered a small set of countries using unbalanced panel data (Jorgenson and Birkholz, 2010). These studies support the idea that national emissions increase with population and economic growth and depend on the sectoral composition of an economy. However, they do not account for the potential endogeneity of key variables (such as economic growth) and, noteworthy, do not engage in sectoral analysis of methane emissions. Also, these studies have focussed only on production-based emissions, what seems too narrow, since the link between national production and consumption patterns has been weakened by the recent trend of globalization of production chains. We address these issues by comprehensively investigating the economic determinants of methane footprints, taking into account global value chains and trade linkages.[3]

Our contributions in this paper are threefold. First, we develop a global panel dataset of national inventories of methane emissions embodied in standard (territorial) production, final production, and consumption activities. In the context of global supply chains and vertical specialization, the attribution of responsibilities in international environmental agreements and the determination of national policy targets and instruments must account for international linkages and potential for outsourcing. Our dataset takes into account cross-border linkages in production and provides valuable information about national (and sectoral) responsibility for emissions at three stages of the supply chain. Second, with these data we conduct economy-wide and sector-specific analyses, capturing the heterogeneity in the sources of methane emissions, which reflect diverse socio-economic drivers including economic development. At the sectoral level, this heterogeneity will determine the scope for mitigation through efficiency gains, which in turn depends on the existence of cleaner alternatives to current (dirty) inputs in the production function, the elasticity of substitution between clean and dirty inputs, and the technological gap between established, dirty technologies and their new, cleaner counterparts. These factors will differ across sectors.[4]

[3] Subak (1995) highlights the importance of accounting for methane embodied in international trade.

[4] Acemoglu et al. (2012) highlighted the role of the elasticity of substitution between clean and dirty inputs and the level of development of clean relative to dirty technologies in the relationship between economic growth and pollution. A higher elasticity of substitution between the two classes of inputs or a lower technology gap between clean and dirty production technologies make it possible to prevent pollution without dramatically compromising growth. The potential for development of new technologies will depend on the research and development (R&D) investments of private agents in response to market incentives (preferences for cleaner production). These investments in turn depend on the prospects of economic growth.

At the macroeconomic level, structural (sectoral) transformation associated with economic growth will be responsible for some of the effects of economic development on aggregate methane emissions. Finally, we explore in detail the relationship between economic development and methane emissions, also allowing for potential nonlinearities.

Our data provide comparable national methane emissions inventories based on territorial production, final production and consumption activities. The dataset is built from underlying data covering 187 economies, grouped into 78 countries and regions and 57 sectors, for the years 1997, 2001, 2004, 2007, and 2011. Following the recent literature on international value chains, methane inventories are calculated based on multi-regional input-output (MRIO) analysis (Koopman et al., 2014; Fernández-Amador et al., 2017). This means that we extend territorial national production inventories, by tracing emissions embodied in intermediate input flows to compute emissions embodied in final production. We also map emissions embodied in trade flows of final goods and services in order to calculate final consumption emissions inventories. Based on these comparable inventories, we identify a number of stylized facts regarding methane emissions worldwide and assess the determinants of economy-wide and sector-specific methane emissions per capita.

We identify four main stylized facts. First, methane mitigation is important for climate change control, especially in the short-term—anthropogenic methane emissions are equivalent to between 25% and 84% of the warming potential of CO_2 emissions from fossil fuel combustion, depending on whether we use a 100-year or a 20-year basis to compute the equivalence, and increased 25% during 1997–2011. Second, developing countries account for the largest part of anthropogenic CH_4 emissions. While high-income countries were able to reduce per-capita emissions between 1997 and 2011, the emissions from developing countries have increased despite considerable gains in CH_4 efficiency. Third, high income countries show net-imports of emissions embodied in goods and services, which are divided in intermediate and final products alike. Finally, there are important differences across sectors concerning the contributions of value added growth and methane efficiency gains, which are likely to affect transaction costs related to environmental regulation.

The econometric results point to a robust, significant and positive effect of economic growth on methane emissions per capita. This relationship is non-linear, characterized by threshold effects. One threshold determines a reduction in the income elasticity of emissions at very high income levels. There is also some less robust evidence for another threshold effect capturing an increase in the income elasticity at lower income levels. Moreover, we detect substantial sectoral heterogeneity concerning the determinants of emissions and the functional form of the income elasticity of methane. Overall, the mix of linear and threshold models found at the sectoral level determines the non-linear patterns detected economy-wide. The livestock sector, but also the transport sector for production inventories, underlie the threshold effect identified at very high levels of development, while the energy, manufacturing, and public administration (waste management) sectors seem to determine the threshold estimated at lower development levels. Notably, more than 40% of total methane emissions are not significantly affected by income per capita. Furthermore, sectoral transformation accompanying economic growth seems to increase methane emissions per capita.

Our results question that preferences for cleaner environment lower methane emissions in more democratic and developed countries. They also highlight the ineffectiveness of the Kyoto Protocol in limiting global CH_4 emissions. Although Annex I ratification has led to a reduction in emissions on the production side, notably from the energy and public administration sectors, we also observe an increase in emissions derived from final production and consumption inventories in Annex I countries, particularly in the agriculture, service and transport sectors. Additionally, openness to international trade is connected to higher emissions from production, what may be driven by methane leakage. Basically, for any climate change mitigation policy to be effective, the existence of international trade linkages needs to be taken into account.

The rest of the paper is organized as follows. The next section provides an overview of methane emission inventories and stylized facts for the period 1997–2011. Section 3 discusses potential socio-economic drivers of methane emissions and outlines our econometric strategy. Section 4 presents the economy-wide and sector specific results. We conclude in Section 5.

2 Stylized facts of national emission inventories

We compute a consistent panel of sectoral methane emissions inventories based on territorial production, final production and consumption activities. This dataset comprises emission inventories for 57 sectors of 78 regions, for the years 1997, 2001, 2004, 2007 and 2011.[5]

Our dataset extends the territorial, production-based dataset of methane emissions developed by the Global Trade Analysis Project (GTAP).[6] First, we generate national (standard, territorial) production-based emission inventories, which are comparable over time.

[5] A detailed explanation of the methodology to construct the emission inventories based on territorial production, final production and consumption activities can be found in Appendix A. An overview of the regions and sectors covered is available in Table B.1 and B.2 in Appendix B.

[6] See Rose and Lee (2008), Rose et al. (2010), Ahmed et al. (2014), Irfanoglu and van der Mensbrugghe (2015). The GTAP CH_4 emissions data cannot be used in a panel framework, since the sources of raw data and/or the methodology for data construction differ across GTAP releases and do not exist for 1997. Also, GTAP yearly releases consist only of methane emissions based on territorial production.

For that purpose, we map methane emissions from the Food and Agriculture Organization (FAO) of the United Nations and statistics from the Emission Database for Global Atmospheric Research (EDGAR) to the 57 sectors of the 78 regions covered. Territorial emission inventories constitute the standard measure of national emissions relevant for multilateral agreements on emissions reduction such as the Kyoto Protocol.

After that, we apply multi-regional input-output (MRIO) techniques to construct inventories of emissions embodied in final production and final consumption activities (footprint measures). Final production inventories collect all emissions embodied in intermediate inputs used in the production of final goods and assign them to the country and sector that produces the final good (supply-side of final products). Consumption-based inventories, by contrast, reflect the demand-side for final products and allocate emissions embodied in the consumption of products from specific sectors to the country in which consumption takes place. To derive these inventories, we combine our territorial production emission inventories with input-output and trade data to construct a global intermediate input requirements matrix. We create an environmentally extended MRIO table by scaling the global requirements matrix to CH_4 emissions and calculate the environmentally extended Leontief-inverse matrix, which collects the direct and indirect CH_4 requirements for a given unit of output per sector and region. We finally derive the final production and consumption based national inventories.

2.1 Global sources of methane and national emission inventories

Table 1 presents the total amount of anthropogenic methane emissions released during the period 1997–2011 in warming potential equivalent to CO_2 emissions from fossil fuel combustion, computed by Fernández-Amador et al. (2016), using two alternative time frames. Although methane has a relatively short atmospheric life-time, 12.4 years, its global warming potential is 72 times that of CO_2 (by equivalent mass) over a 20-year period and 21 times over a 100-year time frame, respectively (IPCC, 2007). The table indicates that although anthropogenic methane emissions are equivalent to 25% of CO_2 emissions on a 100-year basis, they are only somewhat lower (84%) than the warming potential of CO_2 emissions over a 20-year period. In addition, global methane emissions increased by 25% between 1997 and 2011. In this sense, methane mitigation is important for climate change control, especially in the short-term.[7]

Figure 1 shows the contribution of the 57 sectors to global methane emissions embodied in territorial production (upper graph) and final production and consumption patterns

[7] Methane also contributes to thermal expansion of the ocean over much longer time scales than its atmospheric life-time (Zickfeld et al., 2017).

	CH_4 (CO_2e, 100y)		CH_4 (CO_2e, 20y)		CO_2
	Mt	% of CO_2	Mt	% of CO_2	Mt
1997	5862.41	25.82	20099.68	88.54	22701.79
2001	5999.47	26.02	20569.60	89.22	23054.30
2004	6410.75	24.28	21979.73	83.25	26403.22
2007	6800.65	23.35	23316.50	80.07	29121.03
2011	7313.50	23.61	25074.85	80.96	30971.11

Table 1: Global CH_4 and CO_2 emissions. Note: CO_2e, 100y and CO_2e, 20y stand for CO_2 equivalents based on a global warming potential over 100 and 20 years, using the conversion factors of 21 and 72, respectively (IPCC, 2007). CO_2 data are available from Fernández-Amador et al. (2016).

(lower graph) as calculated in our database. Production-based emissions are concentrated in relatively few sectors, which correspond to very heterogeneous economic processes such as livestock breeding (34.7%), drilling and transportation of fossil fuels (25.1%), public administration (19.9%, which is mainly waste management), and rice cultivation (7.8%). Footprint-based emissions, by contrast, are spread across sectors more evenly as a result of domestic and international inter-sectoral supply-chain relations. Particularly, much of the methane produced by rice cultivation and livestock breeding is used in food processing sectors, while emissions from fossil fuel drilling are mainly used by industrial activities and transportation services.

Table 2 reports a summary of the three CH_4 inventories for the most important producers and consumers of methane emissions, which taken together represent roughly 80% of produced emissions between 1997 and 2011, and for the four income groups as defined by the World Bank. The first six columns report total CH_4 emissions in megatons (Mt) of CO_2 equivalents and as world shares for each emission inventory.[8] The last four columns summarize CH_4 emissions per capita (in tons) and per value added (as kg per USD) for production- and consumption-based inventories.[9]

The bulk of anthropogenic methane emissions is concentrated in developing economies, especially in the upper and lower-middle income groups. Together, these groups accounted for 72% of produced and 64% of consumed CH_4 in 1997.[10] The dynamics of emissions between 1997 and 2011 were very different for developed and developing economies. Emissions in developing countries grew considerably for all three methane inventories, especially in upper-middle income countries, which include the BRIC countries Brazil, Russia and China, and in low-income countries. For the high income group, by contrast, CH_4 emis-

[8] CO_2 equivalents of methane are based on a global warming potential (GWP) over 100 years; this equivalence is commonly used in the literature.

[9] Pollution intensity (efficiency) is often measured in pollution per GDP. We opt for a value added based measure in order to align the definition of the economic aggregate and the flux of methane emissions derived from it.

[10] This contrasts with data for CO_2 releases from fossil fuel combustion, where most of the emissions are released by developed economies (see Fernández-Amador et al., 2016).

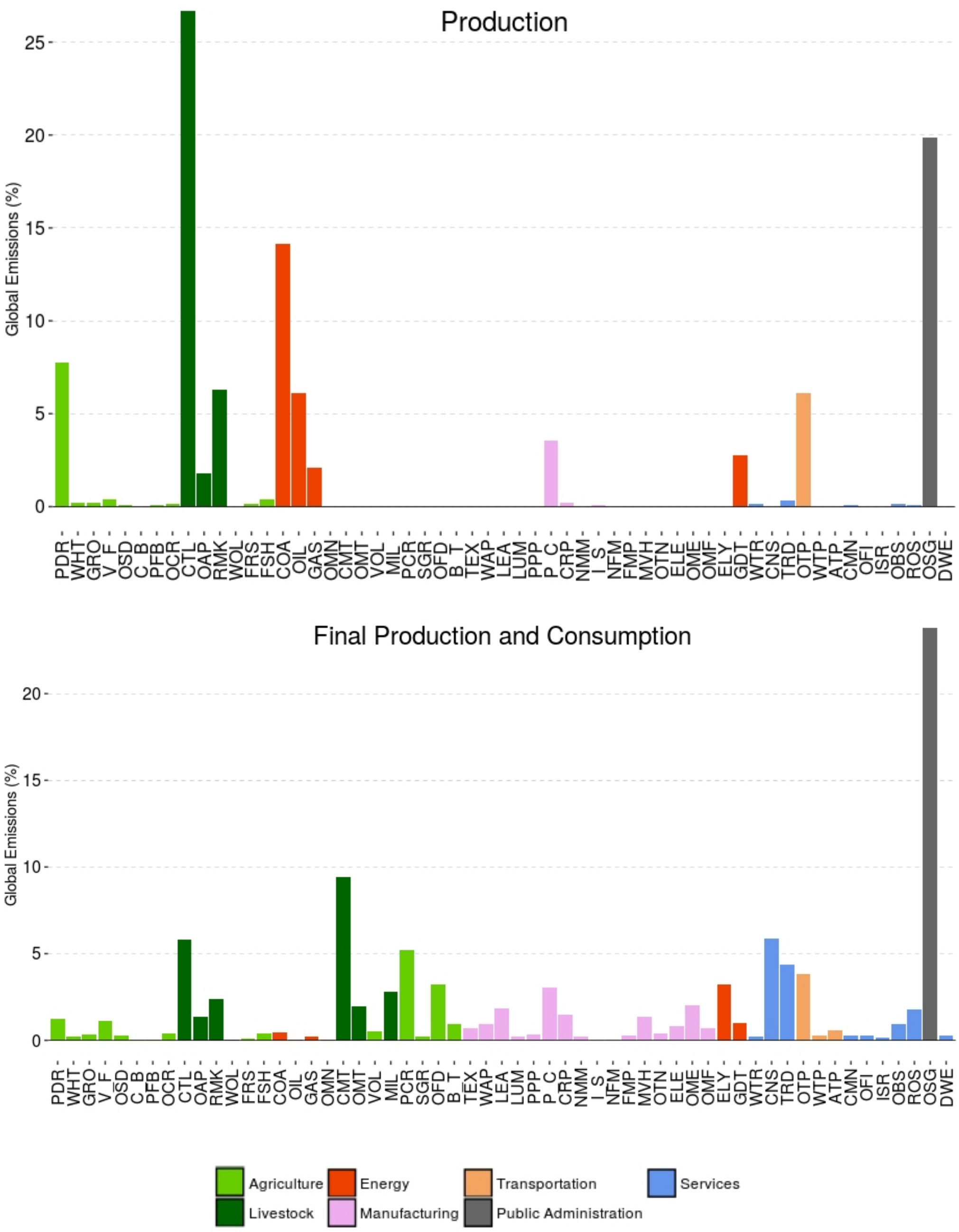

Figure 1: Sector shares of global CH_4 emissions, three inventories (average 1997–2011). The barplots show CH_4 emissions associated with production (upper plot) and consumption and final production (lower plot) in each of the 57 sectors as share of global methane emissions. On a global level methane emissions associated with final production and final consumption are equal. For a definition of sector-abbreviations and for the assignment of each sector to the broad sectors represented by the different colors, see Table B.2 in Appendix B.

	Total CH_4*						CH_4 pc*		CH_4 per VA*	
	production		**final prod.**		**consumption**		**prod.**	**cons.**	**prod.**	**cons.**
	(Mt)	(shr.)	(Mt)	(shr.)	(Mt)	(shr.)	(t per capita)		(kg/USD)	
					1997					
High Income	1496.75	25.53	1882.10	32.10	2009.19	34.27	1.52	2.04	0.07	0.10
Australia	117.30	2.00	86.90	1.48	71.41	1.22	6.35	3.86	0.33	0.20
EU 15	471.63	8.04	659.80	11.25	712.22	12.15	1.27	1.92	0.07	0.10
EEU	156.15	2.66	160.88	2.74	155.46	2.65	1.46	1.45	0.56	0.50
USA	571.54	9.75	657.94	11.22	714.18	12.18	2.16	2.70	0.07	0.09
Upper Middle	2433.79	41.52	2174.01	37.08	2092.06	35.69	1.10	0.94	0.62	0.53
Brazil	289.14	4.93	301.21	5.14	301.16	5.14	1.79	1.86	0.39	0.40
Russia	444.11	7.58	332.37	5.67	334.54	5.71	3.02	2.28	1.16	0.88
China	868.77	14.82	799.34	13.64	731.02	12.47	0.71	0.60	1.23	1.03
Mexico	94.60	1.61	94.47	1.61	94.08	1.60	1.00	0.99	0.27	0.28
Middle East	200.17	3.41	138.32	2.36	142.80	2.44	1.27	0.91	0.44	0.31
Lower Middle	1812.98	30.93	1689.48	28.82	1647.58	28.10	0.76	0.69	1.27	1.11
Former SU	211.47	3.61	187.60	3.20	170.80	2.91	1.53	1.24	1.93	1.50
India	552.82	9.43	550.69	9.39	540.87	9.23	0.58	0.56	1.57	1.51
Indonesia	153.50	2.62	141.32	2.41	143.01	2.44	0.76	0.71	0.79	0.74
RSA	112.63	1.92	112.02	1.91	109.89	1.87	0.64	0.63	1.85	1.70
SSA	362.86	6.19	316.47	5.40	309.12	5.27	0.90	0.77	2.43	2.02
Low Income	118.89	2.03	116.81	1.99	113.58	1.94	0.57	0.54	1.75	1.58
					2011					
High Income	1330.18	18.19	1862.66	25.47	1971.02	26.95	1.23	1.83	0.05	0.08
Australia	152.85	2.09	96.35	1.32	83.18	1.14	6.84	3.72	0.26	0.14
EU 15	377.51	5.16	641.30	8.77	678.23	9.27	0.94	1.69	0.05	0.09
EEU	134.10	1.83	151.88	2.08	149.93	2.05	1.32	1.47	0.28	0.28
USA	486.94	6.66	619.17	8.47	681.79	9.32	1.56	2.19	0.05	0.07
Upper Middle	3453.37	47.22	3122.14	42.69	3036.25	41.52	1.36	1.20	0.44	0.38
Brazil	407.19	5.57	394.44	5.39	387.11	5.29	2.07	1.97	0.40	0.37
Russia	549.30	7.51	368.27	5.04	372.21	5.09	3.84	2.60	1.04	0.66
China	1451.27	19.84	1426.06	19.50	1308.10	17.89	1.08	0.97	0.51	0.45
Mexico	108.54	1.48	107.26	1.47	109.31	1.49	0.91	0.92	0.18	0.18
Middle East	335.29	4.58	220.58	3.02	256.35	3.51	1.52	1.16	0.35	0.29
Lower Middle	2360.64	32.28	2167.21	29.63	2147.30	29.36	0.77	0.70	0.85	0.73
Former SU	256.67	3.51	201.26	2.75	196.90	2.69	1.84	1.41	1.18	0.91
India	658.59	9.01	666.90	9.12	643.27	8.80	0.54	0.53	0.63	0.59
Indonesia	210.47	2.88	185.24	2.53	190.92	2.61	0.86	0.78	0.67	0.58
RSA	172.96	2.36	174.46	2.39	172.70	2.36	0.74	0.74	1.45	1.26
SSA	489.26	6.69	429.97	5.88	444.12	6.07	0.83	0.76	1.72	1.40
Low Income	169.31	2.32	161.49	2.21	158.93	2.17	0.59	0.55	1.37	1.28

Table 2: Main indicators for CH_4 inventories: 1997 and 2011. Selected regions. Note: *Data is reported as CO_2 equivalents with respect to global warming potential for a 100 year time frame. pc stands for per capita, VA stands for value added, Mt stands for megatons, shr. for world shares, t for ton, kg for kilogram. EEU stands for Eastern European Union members joining the Union in 2004 and 2007, including the upper-middle income countries Bulgaria and Romania; for the group totals these countries are assigned to their respective income group. RSA stands for the Rest of South Asia area, SSA for the Rest of Sub-Saharan Africa region. For details on the countries covered in these regions see Table B.1 in Appendix B.

sions derived from production declined by 11% between 1997 and 2011; the decline was less pronounced for emissions embodied in final production and consumption.

High-income countries show, on average, the highest level of methane emissions per person, followed by upper-middle and lower-middle income countries. In high-income countries, per capita emissions consumed are larger than per capita CH_4 embodied in production, reflecting the fact that they are net importers of emissions. By contrast, for the other income categories the opposite is true. During 1997–2011, emissions per capita grew most strongly in upper-middle income countries, whereas they increased only slightly in the lower-middle and low-income groups and even experienced a decrease in the high-income countries. Large producers of fossil fuels show rather high per capita emissions compared to the other countries in their respective income groups and are usually also net exporters of emissions, as the production-based per capita inventories considerably exceed the consumption-based ones.

High-income economies show by far the highest methane efficiency per unit of value added, followed by upper-middle and lower-middle income countries; low-income economies are particularly methane intensive. Yet, the methane efficiency of high-income countries is higher for production than for consumption inventories whereas the opposite is the case in the other income groups. Between 1997 and 2011, improvements in methane efficiency were especially important in the lower- and upper-middle income countries, which were able to reduce the methane content of value added by about one third. The high- and low-income groups showed only slightly lower improvements in the methane content of value added from production and comparably smaller improvements in the CH_4 efficiency embodied in consumption.

2.2 Decomposition of changes in methane emissions

Figure 2 decomposes the growth rate of total emissions between 1997 and 2011 (marked by the black dots) from the three emission inventories and for the four income groups into changes in methane intensity (dark bar), changes in value added per capita (light bar), and population growth (white bar). In general, the expansion of value added per capita and population growth have increased emissions, whereas efficiency gains had the opposite effect. Only in high-income countries, the rather moderate growth rates of population and value added did not outweigh efficiency improvements and, as a result, total emissions decreased during 1997–2011. In the other income groups, the expansion of value added per capita and population surpassed efficiency gains and yielded increasing methane releases.

Figure 3 shows the decomposition of emissions growth at the sectoral level and reveals that the aggregate pattern shown in Figure 2 hides important sector-specific characteristics.[11]

[11] For the sectoral analysis we aggregate the 57 sectors in our dataset to seven sectors: agriculture, livestock, energy, manufacturing, services, transport, and public administration. A detailed definition of these sectors is available in Table B.2 in Appendix B.

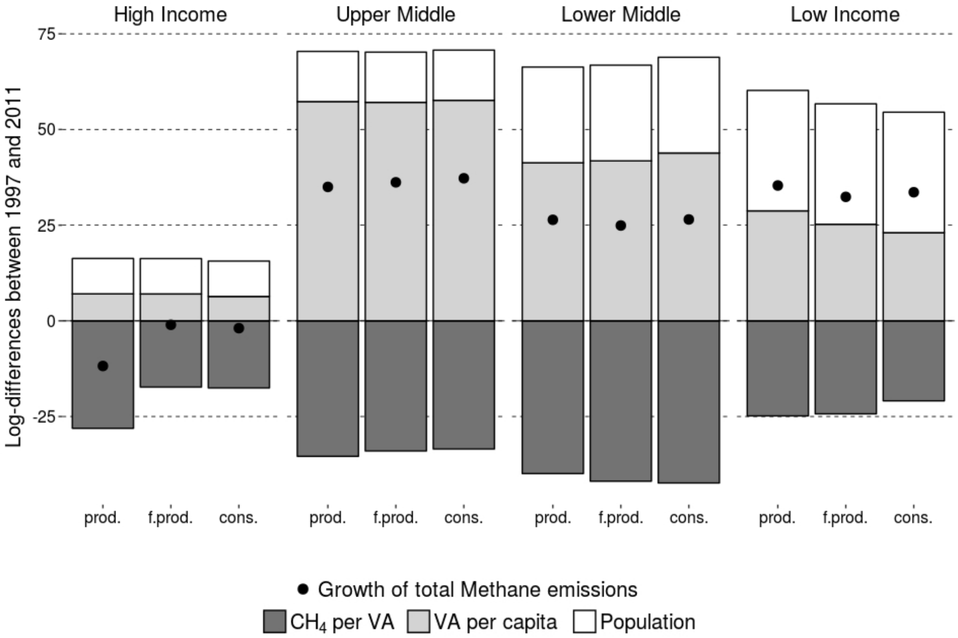

Figure 2: Change in components of the Kaya-identity (1997–2011). Note: The barplots show the log-differences of the components of the Kaya-identity between 1997 and 2011 for the four World Bank income groups. The Kaya identity decomposes total CH_4 emissions into CH_4 per value added, value added per capita, and population, according to the formula $CH_4 = \frac{CH_4}{VA} \cdot \frac{VA}{pop} \cdot pop$. The data is presented for the three inventories in our dataset: standard production (prod.), final production (f.prod.) and consumption (cons.). Additionally we show the growth rate of total emissions (in log-differences), marked as black dot.

Although efficiency gains were important on the aggregate level, they were not realized to the same extent in every economic sector. This points towards different potential for emission abatement in different sectors. Improvements in efficiency were particularly limited in the manufacturing and transport sectors, which even experienced an increase in the CH_4 intensity of value added in most income groups. Also the primary sectors have shown lower mitigation potential as compared to other sectors; the livestock sector in low-income countries and the agriculture sector in high-income economies were characterized by a slight decline in methane efficiency. In all income groups the largest efficiency gains took place in the energy, services, and public administration sectors.

The economy-wide changes in value-added per capita are also to a large extent influenced by sectoral shifts of production and consumption patterns. The energy and the public administration sectors (the latter includes landfills and sewage treatment) experienced a strong growth during 1997–2011 in all income groups. In low-income countries also the manufacturing sector expanded considerably, whereas for the other income groups the service sector was among the sectors that grew more strongly. In high-income countries, the primary, manufacturing, and transport sectors even decreased their shares in value added.

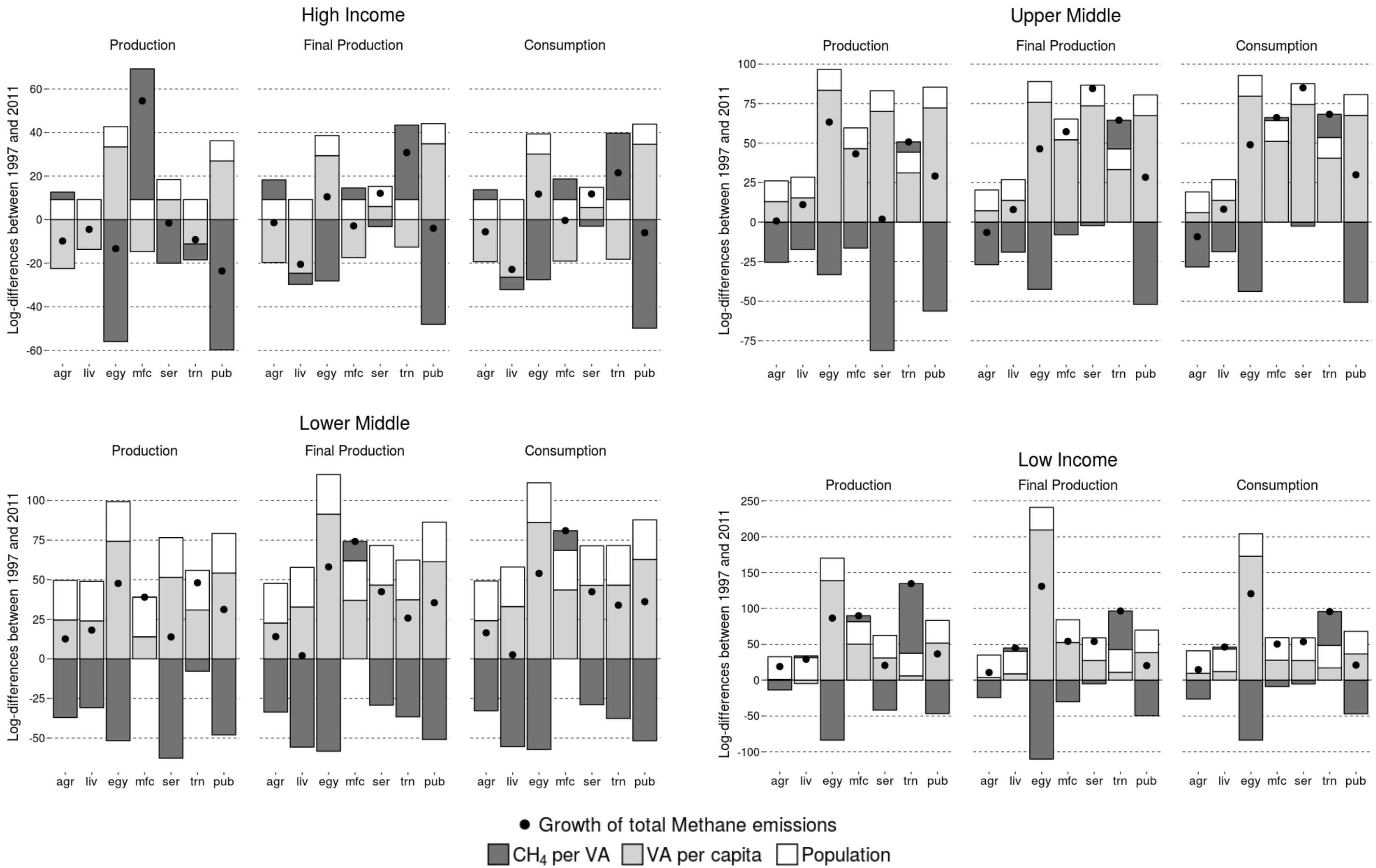

Figure 3: Change in components of the Kaya-identity (1997 – 2011, sectors). Note: The barplots show the log-differences of the components of the Kaya-identity between 1997 and 2011 for seven sectors of the four World Bank income groups. The Kaya identity decomposes sectoral CH_4 emissions into CH_4 per value added, value added per capita, and population, according to the formula $CH_4 = \frac{CH_4}{VA} \cdot \frac{VA}{pop} \cdot pop$. Except for population all the variables in the formula are measured at the sectoral level. The data is presented for the three inventories in our dataset: standard production, final production and consumption. Additionally we show the growth rate of total sectoral emissions (in log-differences), marked as black dot.

These patterns are consistent with the structural shifts usually associated with economic development (Kuznets, 1973, Herrendorf et al., 2013) and highlight the importance of analyzing emissions at the sectoral level.

2.3 Methane embodied in international trade

Table 3 describes the flows of methane emissions embodied in international trade. It reports the CH_4 content of exports and imports scaled to production-based emissions, net-exports of emissions embodied in intermediates and total trade, indicators for emission leakage, and measures of methane intensity of international trade.

As a result of intensifying globalization, the ratio of traded to total methane emissions increased from 18.5% to 22.9% between 1997 and 2011, particularly in high-income countries. The group of high-income countries traded embodied emissions more intensively than their less developed counterparts. This is largely driven by the CH_4 content of imports, since the share of exported methane emissions scaled to total production-based emissions is relatively low in most regions.[12] With the exception of fuel exporters such as Australia, the CH_4 content of imports is rather large in the group of high-income countries, as exemplified by the EU-15 and the USA, where imported emissions amounted to 92% and 53% of production-based emissions in 2011.

The higher CH_4 content of imports relative to exports in high-income countries again confirms that they are net-importers of methane. Their trade balance of emissions embodied in trade in intermediates (BEETI) and in total trade (BEETT), scaled to production-based emissions, is typically negative. This imbalance grew between 1997 and 2011, with a growing reliance of high-income countries on net-imports of CH_4, mirrored by increased net-exports in middle- and low-income countries. Also shown by BEETI and BEETT, traded methane emissions are embodied in traded intermediates and final goods alike.[13]

The net-importation of methane in high-income countries, many of which are bound by emission targets specified in the Annex I of the Kyoto Protocol, points towards potential for methane leakage. Emissions embodied in imports from non-Annex I countries scaled to emissions from territorial production are the largest in the group of high-income countries, particularly in the EU-15 and USA, whereas they are below the high-income average in Australia and EEU. In middle- and low-income countries this indicator is typically much lower, though during 1997–2011 it doubled in the upper-middle and low-income groups and increased by a factor of 2.7 in the lower-middle income group, reflecting the

[12] Exceptions are large fossil fuel exporters, such as Australia, Russia, and the Middle East.

[13] This contrasts with CO_2 emissions, which are mainly embodied in trade in intermediates, because of their origin in energy usage (see Fernández-Amador et al., 2016).

	Embodied CH_4*				CH_4 leakage*		CH_4 per VA*	
	exports	**imports**	**BEETI**	**BEETT**	**prod.**	**imports**	**exports**	**imports**
	(shares of prod. emissions)				(shares of)		(kg/USD)	
				1997				
High Income	18.21	52.43	-25.75	-34.24	32.91	62.76	0.10	0.31
Australia	48.40	9.27	25.92	39.13	5.95	64.20	0.99	0.19
EU 15	8.40	59.41	-39.90	-51.01	35.59	59.90	0.05	0.38
EEU	22.87	22.43	-3.03	0.44	9.56	42.60	0.49	0.35
USA	11.63	36.59	-15.12	-24.96	25.50	69.70	0.09	0.27
Upper Middle	22.13	8.10	10.67	14.04	5.23	64.60	0.72	0.25
Brazil	3.18	7.34	-4.17	-4.16	5.51	75.08	0.18	0.30
Russia	32.04	7.37	25.16	24.67	5.54	75.10	2.10	0.49
China	19.12	3.26	7.99	15.86	1.86	56.93	1.12	0.19
Mexico	12.83	12.28	0.14	0.55	4.07	33.17	0.16	0.16
Middle East	45.92	17.26	30.90	28.66	9.17	53.12	0.68	0.25
Lower Middle	14.60	5.48	6.81	9.12	2.74	49.97	1.06	0.33
Former SU	29.40	10.17	11.29	19.23	0.63	6.15	2.57	0.76
India	4.58	2.42	0.39	2.16	1.87	77.17	0.75	0.33
Indonesia	15.08	8.24	7.94	6.83	4.52	54.81	0.53	0.29
RSA	6.36	3.92	0.54	2.44	3.03	77.14	0.90	0.38
SSA	16.82	2.27	12.78	14.81	1.55	68.26	1.73	0.21
Low Income	8.22	3.75	1.75	4.47	3.03	80.88	1.22	0.37
				2011				
High Income	23.03	71.36	-40.03	-48.18	46.78	65.56	0.08	0.27
Australia	60.57	14.99	36.97	45.58	11.29	75.33	0.83	0.20
EU 15	11.94	91.59	-69.88	-79.66	57.81	63.12	0.04	0.32
EEU	23.50	35.31	-13.26	-11.81	16.01	45.34	0.23	0.24
USA	13.46	53.48	-27.16	-40.02	39.44	73.75	0.07	0.25
Upper Middle	25.87	13.74	9.59	12.08	9.94	72.37	0.49	0.25
Brazil	12.66	7.73	3.13	4.93	5.74	74.24	0.48	0.23
Russia	40.29	8.05	32.96	32.24	6.03	74.93	1.73	0.27
China	19.49	9.63	1.74	9.86	6.64	68.99	0.49	0.21
Mexico	19.77	20.47	1.19	-0.70	10.25	50.05	0.17	0.17
Middle East	53.06	29.52	34.21	23.54	21.72	73.58	0.44	0.31
Lower Middle	19.15	10.11	8.19	9.04	7.41	73.28	0.76	0.31
Former SU	32.55	9.27	21.59	23.29	4.19	45.23	1.13	0.32
India	11.86	9.53	-1.26	2.33	7.48	78.55	0.51	0.30
Indonesia	22.76	13.47	11.99	9.29	10.05	74.57	0.72	0.34
RSA	6.98	6.83	-0.87	0.15	5.79	84.70	0.90	0.38
SSA	16.60	7.37	12.12	9.23	6.04	82.00	1.09	0.33
Low Income	13.03	6.91	4.62	6.13	6.22	90.04	0.84	0.44

Table 3: CH_4 emissions embodied in trade: 1997 and 2011. Selected regions and income groups. Note: *Data are reported as CO_2 equivalents with respect to global warming potential for a 100 year time frame. BEETI and BEETT stand for net balance of emissions embodied in trade in intermediates and total trade, respectively. EEU stands for Eastern European Union members joining the Union in 2004 and 2007. The region includes the upper middle income countries Bulgaria and Romania. For the development group aggregates these countries were assigned to the upper middle income group, however. RSA stands for the Rest of South Asia area, SSA for the Rest of Sub-Saharan Africa region. For details on the countries covered in these regions please refer to Table B.1 in Appendix B. Income groups are based on World Bank definitions.

growing importance of trade among developing countries. The importance of developing economies in methane embodied in trade flows appears even clearer when we look at emissions embodied in imports from non-Annex I members as a share of total imported emissions. This other indicator of methane leakage is rather high in all income groups and has been growing over the period considered.

In terms of methane intensity, imports of high-income countries are, on average, more intensive in CH_4 content per unit of value added than exports. For the other income groups the opposite applies, with a notable difference in the low-income group. A comparison of these figures to the CH_4 intensities reported in Table 2 reveals that exports of the high- and upper-middle income groups are typically more CH_4 intensive than their national production, whereas the CH_4 intensity of imports is higher than the one of consumption in the high-income group. For the lower-middle and low-income groups, trade flows show larger methane efficiency than production and consumption aggregates; that is, the aggregate of domestic emissions (produced and consumed in the territory) is less environmentally efficient than the sectors oriented to trade. Finally, we observe a general decrease in the CH_4 intensity of trade over time, reflecting gains in methane efficiency that were also visible from Table 2.

3 Empirical specification and econometric methodology

3.1 Explanatory variables and data sources

Anthropogenic methane emissions originate from very different sources, which depend on diverse socio-economic drivers and, notably, on the relationship between economic development and emissions. Economic development, proxied by income per capita, has been found to be positively connected to methane emissions. Various authors have found evidence for non-linear effects of economic growth on other greenhouse gas emissions; thus, we allow for non-linearities of different forms in the income-methane relationship.[14]

Economic development goes often hand in hand with other transformations (Kuznets, 1973), e.g. demographic transitions, urbanization, changing specialization and more energy-intensive production patterns, capital accumulation and technological innovation, and stronger preferences for a clean environment. The effects of population growth and urbanization are a priori ambiguous: A higher population density may imply efficiency

[14] For an inverted-U relationship between income and pollution emissions see e.g. Frankel and Rose (2005), Grossman and Krueger (1993), Kearsley and Riddel (2010), Millimet et al. (2003), Cole (2004), and Schmalensee et al. (1998). For a piecewise linear relationship see e.g. Aslanidis and Iranzo (2009) and Fernández-Amador et al. (2017). Rosa et al. (2004) tested for a polynomial relationship between income and methane emissions but did not find statistically significant effects of the squared income term.

gains in the provision of services, transport, and energy supply; yet population growth increases the demand for goods and services and raises emissions.[15] Similarly, urbanization may capture structural change associated with development and can affect emissions if energy consumption is higher in urban areas.

The effect of specialization and trade patterns on a country's environmental performance is theoretically unclear. On the one side, trade may favor transfer of cleaner technologies and contribute to reducing methane emissions (Grossman and Helpman, 1995). On the other side, environmental regulation can also affect the re-location of industries across countries; in this case, trade flows would be related to opportunities to avoid strict regulations (methane leakage) and affect negatively the environment by increasing emissions (Copeland and Taylor, 2004). We test for the impact of trade openness on emissions and also control for food and fuel (including coal, gas and oil) exports as a share of total exports.[16] We also include the rents from fossil fuel production (including coal, gas and oil) as a share of GDP, since large producers of fossil fuels might rely more heavily on cheap but dirty energy derived from it.

Several variables relate to citizens' preferences for a cleaner environment. The Kyoto Protocol covers methane and four other GHGs besides CO_2. We include a dummy variable equal to one in case of ratification of the Kyoto Protocol and Annex I membership. Other variables are included to capture the effect of institutional development that can affect pollution patterns. The effect of democracy on emissions is theoretically ambiguous. On the one hand, demand for a cleaner environment is more likely to influence policy making in more democratic regimes, while, on the other hand, lobbies might campaign against environmental regulation, affecting adversely the potential for future pollution mitigation.[17] Additionally, we control for different categories of the Human Development Indicator to capture potential qualitative effects from socio-economic development (see Fernández-Amador et al., 2017).

In the econometric analysis we explicitly account for potential endogeneity of economic growth and Annex I ratification with respect to methane emissions. Economic growth

[15] See e.g. Fernández-Amador et al. (2017), Frankel and Rose (2005), Harbaugh et al. (2002) and Torras and Boyce (1998) for studies using population density as a determinant of different GHG emissions.

[16] For studies that tested the effect of trade openness on other GHG emissions, see e.g. Antweiler et al. (2001), Cole (2004), Cole and Elliott (2003), Fernández-Amador et al. (2017), Frankel and Rose (2005), Harbaugh et al. (2002), and Kearsley and Riddel (2010). Jorgenson and Birkholz (2010) proposed using food and fuel exports as a share of total exports to capture globalization-induced pressure on producers of these products to adapt environmental standards.

[17] Aichele and Felbermayr (2012, 2015) and Fernández-Amador et al. (2017) investigated the effect of the Kyoto Protocol on CO_2 emissions. Fernández-Amador et al. (2017), Frankel and Rose (2005), and Aichele and Felbermayr (2012), among others, tested the impact of democracy on different GHG emissions. Furthermore, Barrett and Graddy (2000) found that an increase in freedom improves environmental quality.

will be endogenous if, for example, growth depends on a country's resource endowments or if environmental regulation limits a country's growth potential (e.g. Stern et al., 1996, Dinda, 2005, Frankel and Rose, 2005). Environmental regulation may be endogenous if countries decide to adopt it based on climate change vulnerability, endowments of renewable energy sources, patterns of comparative advantage, or prospects of decreasing emissions (e.g. Aichele and Felbermayr, 2012, 2015, Fernández-Amador et al., 2017). We instrument current income with three years lagged income and investment growth, and Annex I membership with the ratification of the Rome Statute of the International Criminal Court (ICC).[18]

We source data on per capita income corrected for purchasing power, population density, the share of fossil fuel rents with respect to GDP, and urbanization from the World Development Indicators (WDI) database. Trade openness and the shares of food and fossil fuel exports with respect to total exports are based on data from GTAP. We use a measure of democracy from the Polity IV database, development categories of the Human Development Index (HDI) from the HDI database, and information concerning the ratification of Annex I and the Rome Statute of the ICC from the UN Treaty Collection Database. Data on investment are from the IMF World Economic Outlook (WEO) database.[19]

3.2 Econometric methodology

We outline the econometric identification of the determinants of CH_4 emissions derived from production, final production, and consumption inventories below. We apply these models subsequently on economy-wide and sectoral CH_4 inventories. Since the failure to account for potential non-linearities between income and emissions could lead to omitted variable bias, we pay attention to the relationship between pollution and income per capita. We first estimate polynomial regressions, including a squared (log) income term among the regressors. Second, we estimate threshold (piecewise-linear) regression models,

[18] For the choice of the instruments see Aichele and Felbermayr (2012, 2015), Fernández-Amador et al. (2017), Frankel and Rose (2005). In models including a squared income term, we instrument this term by using lagged income squared as additional instrument. In the threshold models we instrument regime-specific effects of income using regime specific terms for lagged income and investment growth as instruments. We acknowledge that also international trade might by affected by reverse causality if the implementation of stringent environmental regulation leads to a decrease in emissions and at the same time induces firms to shift heavily polluting activities to other countries from which the produced goods are imported. This potential endogeneity has been tackled in cross sectional studies on GHG emissions using gravity estimators (e.g. Frankel and Rose, 2005, Managi et al., 2009). Yet, in our panel setup we cannot use the gravity-based trade instrument together with fixed effects, as the gravity framework makes use of time-invariant explanatory variables which are captured by the fixed effects in the main equation.

[19] A complete description of the data and a summary of data sources is available in Table B.4 in Appendix B. Summary statistics for the variables used are reported in Table B.5.

in which the threshold is endogenously estimated (see Hansen, 1999, Caner and Hansen, 2004).[20]

The polynomial models of the determinants of production- and footprint-based CH_4 emissions per capita take the form:

$$E_{it} = \alpha + \beta_1 y_{it} + \beta_2 y_{it}^2 + \gamma_1 a_{it} + \gamma_2 t_{it} + Z_{it}'\delta + \nu_t + u_{it}, \tag{1}$$

where E_{it} stands for annual (logged) CH_4 emissions per capita of region i in period t, subsequently from production, final production, and consumption inventories. y_{it} is the logarithm of annual real GDP per capita in purchasing power parity (PPP) dollars, a_{it} is a dummy variable for Annex I membership, t_{it} is a measure of trade openness, Z_{it} is a vector of controls and ν_t is a vector of time fixed effects. $\beta_1, \beta_2, \gamma_1$, and γ_2 are coefficient estimates, δ is a coefficient vector, and u_{it} are the disturbances. As control variables, Z, we include food exports and fuel exports as share of total exports, the natural logarithm of population density, urbanization, fossil rents as a share of GDP, a democracy index, and development group dummies.

We estimate equation (1) using pooled OLS, such that $u_{it} \sim N(0, \sigma^2)$, and FE estimators, such that $u_{it} = \mu_i + e_{it}$, where μ_i are individual fixed effects and $e_{it} \sim N(0, \sigma^2)$. The individual fixed effects take into account unobserved heterogeneity between countries and mitigate omitted variable bias. In alternative specifications we account for the potential endogeneity of income (and its square) and Annex I ratification following the instrumentation strategy described above. We estimate the instrumental variable regression models using 2-stage Generalized Methods of Moments (GMM).

If β_1 and β_2 are both statistically significant and the estimate of the turning point is in sample, there will be evidence for a polynomial relationship between income and CH_4 emissions. Otherwise, linearity cannot be rejected.[21]

Additionally, we consider the threshold (piece-wise linear) specification

$$E_{it} = \alpha + \sum_{k=1}^{m} [\beta_k y_{it} I(\tau_{k-1} < q_{it} \leq \tau_k)] + \gamma_1 a_{it} + \gamma_2 t_{it} + Z_{it}'\delta + \nu_t + u_{it}, \tag{2}$$

[20] We test the threshold model against a model without threshold, following the methodology of Hansen (1996, 1999). In case we detect evidence for non-linearities based on both the polynomial and the threshold model, we report the results of the model that minimizes the sum of squared residuals.

[21] When linearity cannot be rejected, we only report the results without the squared income term in the main text of the paper. Results including the squared term are available in Appendix C.

where all variables and coefficient vectors are defined as before and the perturbations $u_{it} = \mu_i + e_{it}$, where $e_{it} \sim N(0, \sigma^2)$, account for individual-specific fixed effects.[22] The indicator function $I(\cdot)$ determines regimes with different income elasticities, which depend on whether the threshold variable q_{it} (in our case the logarithm of GDP per capita five years lagged) is included in the estimated threshold interval $(\tau_{k-1}, \tau_k]$; $k = 1, \ldots, m$, where m is the number of regimes. The thresholds τ_k are contained in the domain of q_{it}, ($\tau_k \in [q_{it}^{min}, q_{it}^{max}]$), where $\tau_0 < q_{it}^{min}$ and $\tau_m = q_{it}^{max}$. The continuous threshold variable q_{it} is assumed to be exogenous. The coefficients of the FE model can be estimated by OLS after double-demeaning cancels time and individual FE, ν_t and μ_i.

The thresholds, τ, are treated as unknown and are consistently estimated (see Hansen 1999, 2000). The least squares estimator for the threshold vector τ is defined as minimizing the concentrated sum of squared errors (conditioned on τ), where minimization is based on a grid search over the domain of the threshold variable q_{it}. We restrict the searchable domain to values of q_{it} such that at least 15% of the observations lie in any regime in order to avoid regimes with too few observations.

Given an additional threshold estimate $\hat{\tau}_k$, we use a likelihood ratio (LR) test where the null hypothesis is the non-existence of the additional threshold. Applying this test sequentially until we reject a new threshold effect, we determine the number of thresholds in (2). This test is non-standard and thus we use a bootstrap procedure based on Hansen (1996) to simulate the asymptotic distribution and to construct the p-values (see Hansen, 1999, for details). $\hat{\tau}$ is a consistent estimator of τ, but its asymptotic distribution is also non-standard. Therefore, following Hansen (1996), we define the confidence interval for $\hat{\tau}$ as the non-rejection region of an LR test with the null of no statistically significant difference between a proposal for τ and $\hat{\tau}$ at the 1% significance level.

To allow for potential endogeneity of income and Annex I ratification, we follow Caner and Hansen (2004) and estimate an IV-FE threshold model using the instruments described above. The IV-FE threshold estimation procedure follows three steps. First, we regress the endogenous variables on the exogenous variables and instruments to obtain the predicted values of the endogenous variables. Second, we regress E_{it} on these predicted values and the exogenous controls and estimate the threshold parameter τ by means of a grid search. We test for the significance of the (new) threshold and compute its confidence interval as described above. Finally, we estimate the coefficients of the second-stage by 2-stage GMM, conditioned on the estimate for the threshold $\hat{\tau}$. The algorithm is repeated conditioned on the threshold estimates until no additional threshold is found.

[22] We only consider threshold models containing individual FE, because the results from the linear models below indicate that there is evidence for omitted variable bias in specifications without FE.

4 Estimation results

4.1 Economy-wide results

Table 4 presents the results of the linear estimations of economy-wide methane emissions. We concentrate on the linear models before turning to the threshold estimates, since we do not find evidence for a polynomial relationship between income and emissions.[23] The OLS specifications for production, final production, and consumption based CH_4 inventories are presented in Panel (1). Panel (2) shows the results for IV models, where we account for the potential endogeneity of income and Annex I ratification by instrumenting these variables as explained in section 3. Panel (3) and (4) report the results of the specifications with country FE and IV-FE.[24]

The results in panels (1) and (2) provide interesting insights concerning the effect of a large set of control variables on CH_4 emissions by exploiting the cross-country variation of the data. They suggest that income is positively related to CH_4 emissions for all three inventories, with an elasticity of between 0.25 and 0.33. We do not detect a significant effect of Annex I ratification. Countries that are more open to trade tend to release more emissions. Additionally, as in Jorgenson and Birkholz (2010), a higher share of food in total exports is connected to higher emissions. The share of fuel exports is insignificant, though. Emissions are significantly lower in more densely populated areas, suggesting efficiency gains in the production and provision of energy and CH_4 intensive goods and services. By contrast, urbanization is related to more CH_4 intensive patterns of final production and consumption. It is likely that urbanization picks up some effects of economic development. Furthermore, large producers of fossil fuels show a higher level of CH_4 embodied in production. The political regime index and the development group dummies are insignificant, pointing to absence of remarkable effects from institutional changes associated with economic development, after controlling for income per capita. Finally, the time dummies are relatively unimportant in explaining variations in CH_4 production, but they capture a decreasing trend in CH_4 embodied in final production and consumption over the period 2007–2011.

[23] The results of the polynomial models are available in tables C.2 and C.3 in Appendix C. They suggest statistically insignificant income elasticities or turning points that lie out of sample.

[24] The Hansen-J test for the validity of our instruments, which is reported in the bottom of Table 4 points towards the validity of the instruments used. The Wu-Hausman test rejects the null of exogeneity of income for the IV regressions. Despite of the theoretical arguments of the endogeneity of Annex I ratification, the exogeneity of this variable cannot be rejected at conventional significance levels. The results of the first stage regressions are reported in table C.1 in Appendix C.

	Panel (1) OLS			Panel (2) IV			Panel (3) FE			Panel (4) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	0.307***	0.327***	0.313***	0.251***	0.291***	0.287***	0.373***	0.300***	0.374***	0.389***	0.284***	0.379***
	(0.062)	(0.049)	(0.046)	(0.064)	(0.049)	(0.047)	(0.069)	(0.065)	(0.086)	(0.082)	(0.090)	(0.116)
Annex I	-0.007	0.035	0.060	0.086	0.057	0.087	-0.048**	0.061**	0.063*	-0.076	0.069	0.058
	(0.065)	(0.045)	(0.040)	(0.118)	(0.075)	(0.067)	(0.024)	(0.030)	(0.033)	(0.057)	(0.068)	(0.059)
Openness	0.116**	0.198***	0.144***	0.115**	0.197***	0.143***	0.081	0.064	0.022	0.089	0.070	0.025
	(0.056)	(0.040)	(0.037)	(0.056)	(0.041)	(0.038)	(0.055)	(0.080)	(0.109)	(0.058)	(0.079)	(0.110)
Food exports	1.157***	0.702***	0.282*	1.173***	0.690***	0.280*						
	(0.278)	(0.200)	(0.156)	(0.276)	(0.201)	(0.157)						
Fuel exports	-0.333	-0.068	0.084	-0.293	-0.054	0.106		-0.217**			-0.207*	
	(0.227)	(0.231)	(0.196)	(0.228)	(0.230)	(0.196)		(0.103)			(0.121)	
ln(Pop. density)	-0.300***	-0.137***	-0.099***	-0.295***	-0.136***	-0.098***						
	(0.019)	(0.015)	(0.015)	(0.019)	(0.015)	(0.015)						
Urbanization	-0.062	0.667***	0.761***	0.031	0.709***	0.785***		0.999*			1.078*	
	(0.218)	(0.166)	(0.156)	(0.227)	(0.170)	(0.156)		(0.535)			(0.626)	
Fossil rents	1.364**	-0.463	-0.685	1.388**	-0.476	-0.694						
	(0.565)	(0.549)	(0.482)	(0.555)	(0.549)	(0.482)						
Polity IV	0.010	0.004	0.004	0.010	0.004	0.004						
	(0.007)	(0.006)	(0.005)	(0.006)	(0.006)	(0.005)						
HDI middle	0.126	-0.058	-0.114	0.179	-0.020	-0.084						
	(0.112)	(0.091)	(0.086)	(0.113)	(0.091)	(0.085)						
HDI high	0.165	-0.054	-0.083	0.224	-0.000	-0.044						
	(0.145)	(0.119)	(0.111)	(0.144)	(0.118)	(0.110)						
HDI very high	0.017	-0.014	-0.030	0.089	0.060	0.022						
	(0.183)	(0.155)	(0.145)	(0.185)	(0.156)	(0.145)						
2001	-0.031	-0.017	-0.018	-0.025	-0.016	-0.018	-0.045***	-0.034**	-0.022	-0.045***	-0.038**	-0.025
	(0.069)	(0.054)	(0.051)	(0.069)	(0.054)	(0.051)	(0.014)	(0.015)	(0.018)	(0.015)	(0.016)	(0.020)
2004	-0.049	-0.029	-0.040	-0.079	-0.036	-0.048	-0.076***	-0.065**	-0.052*	-0.068**	-0.073*	-0.055
	(0.072)	(0.056)	(0.050)	(0.081)	(0.061)	(0.056)	(0.022)	(0.030)	(0.029)	(0.028)	(0.043)	(0.040)
2007	-0.065	-0.081	-0.099**	-0.094	-0.089	-0.107*	-0.129***	-0.122***	-0.112***	-0.124***	-0.128**	-0.115**
	(0.072)	(0.056)	(0.050)	(0.077)	(0.061)	(0.055)	(0.029)	(0.038)	(0.041)	(0.037)	(0.054)	(0.054)
2011	-0.074	-0.116**	-0.137***	-0.106	-0.124*	-0.145**	-0.146***	-0.144***	-0.133**	-0.143***	-0.152**	-0.136**
	(0.074)	(0.059)	(0.051)	(0.079)	(0.064)	(0.057)	(0.032)	(0.044)	(0.051)	(0.041)	(0.062)	(0.064)
Constant	-3.935***	-3.797***	-3.499***	-3.528***	-3.530***	-3.304***						
	(0.477)	(0.355)	(0.341)	(0.493)	(0.362)	(0.345)						
Hansen-J (p)	-	-	-	0.451	0.254	0.218	-	-	-	0.310	0.311	0.325
Wu-Hausman Inc. (p)		-	-	0.0019	0.0018	0.0108	-	-	-	0.6825	0.7734	0.8710
Wu-Hausman Ann.I. (p)		-	-	0.3353	0.7120	0.6072	-	-	-	0.5483	0.8138	0.9639
N	390	390	390	390	390	390	390	390	390	390	390	390
R^2	0.639	0.751	0.784	0.637	0.751	0.783	0.983	0.977	0.967	-	-	-
R^2 within	-	-	-	-	-	-	0.179	0.172	0.131	0.173	0.170	0.131

Table 4: Economy-wide results. Note: R^2 within refers to the R^2 within country.

Panels (3) and (4) show the results of specifications including individual fixed effects which correct for potential bias from omitted time-invariant variables.[25] The individual-specific FE are jointly highly statistically significant, whereas many variables turn insignificant as a consequence of their small time variation.[26] The results confirm the positive effect of income on CH_4 emissions, but suggest a somewhat higher income elasticity (0.28-0.39).[27] Annex I ratification is connected to significantly lower emissions in production inventories but to higher emissions stemming from final production and consumption. This suggests that even though members of the Annex I have reduced their produced emissions, their CH_4 footprints became larger. Nevertheless, the significant effect of Annex I disappears when accounting for the potential endogeneity of its ratification.[28] Trade openness turns insignificant like the remaining variables. Only fuel exports and urbanization appear significant in final production inventories. The production structure of large fossil fuel producers explains the negative effect of fuel exports. Countries that specialize in fossil fuel production tend to produce less final products, because fossil fuels are mainly used as intermediates. Thus, fossil fuel exporters emit less CH_4 from final production. By contrast, urbanization has a positive effect on CH_4 embodied in final products. It may be capturing part of the effect of economic growth on emissions per capita, since it is related to economic development. Finally, the time effects suggest, ceteris paribus, a decreasing global trend in all emission inventories during the whole period of analysis.

Although a polynomial relationship between income and CH_4 emissions per capita has been rejected, it is possible to test for other forms of non-linearities. In Table 5 we allow for threshold effects in the relation between income and emissions.[29] The results provide evidence for the existence of threshold effects in all three inventories. The middle part of the table reports the value of the threshold estimates, their lower and upper

[25] The inclusion of individual FE is equivalent to exploiting the within-country time-variation present in the data.

[26] To optimize efficiency in the estimations, we exclude insignificant regressors. We report only the results for our baseline set of controls and of variables that are statistically significant at least at the 10% level. The individual-specific FE are jointly highly statistically significant also if they are included together with the full set of regressors (see Table C.3 in Appendix C).

[27] Urbanization and fuel exports have statistically significant effects on CH_4 embodied in final production, but remain insignificant in production and consumption inventories. For the final production inventory, urbanization seems to pick up part of the positive effect of income per capita. For CH_4 consumption, urbanization is close to be statistically significant at the 10% level, with a quantitatively similar effect as for final production. Omitting urbanization and fuel exports from the specifications for final production inventories results in a slightly larger income-elasticity (0.32 for FE and IV-FE).

[28] Based on the Wu-Hausman endogeneity test, we cannot reject the exogeneity of Annex I ratification and GDP per capita in the FE specifications. Yet, since theoretical arguments suggest that these variables are endogenous, we instrument them. Our IV-FE estimates are thus conservative, in the sense that they are consistent also if GDP per capita and Annex I are indeed endogenous, though they are inefficient compared to the uninstrumented FE estimates.

[29] The specifications include the same control variables as the FE models from before, together with individual and time fixed effects. For consumption inventories we add urbanization to the list of regressors since it turns out as statistically significant in the threshold specifications.

	Panel (1) FE			Panel (2) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income), reg. 1	0.312 ***	0.235 ***	0.283 ***	0.371 ***	0.238 ***	0.298 **
	(0.066)	(0.059)	(0.082)	(0.079)	(0.084)	(0.119)
ln(Income), reg. 2	0.324 ***	0.245 ***	0.294 ***	0.365 ***	0.227 ***	0.284 **
	(0.065)	(0.058)	(0.081)	(0.080)	(0.086)	(0.121)
ln(Income), reg. 3	0.316 ***	0.236 ***	0.282 ***			
	(0.065)	(0.058)	(0.082)			
Annex I	-0.033	0.080 ***	0.100 ***	-0.079 *	0.123 *	0.141 **
	(0.023)	(0.028)	(0.036)	(0.044)	(0.072)	(0.071)
Openness	0.096 **	0.078	0.029	0.061 *	0.068	0.006
	(0.048)	(0.073)	(0.097)	(0.034)	(0.069)	(0.086)
Fuel exports		-0.232 **			-0.197 *	
		(0.099)			(0.115)	
Urbanization		1.052 **	1.118 *		1.144 *	1.131 *
		(0.506)	(0.580)		(0.615)	(0.675)
First threshold (value)	9.307	10.411	10.411	10.445	10.411	10.411
99% CI lower bound	9.294	10.370	10.382	10.409	10.369	10.382
99% CI upper bound	9.379	10.469	10.469	10.483	10.448	10.444
Bootstrap p-value	0.016	0.002	0.004	0.038	0.000	0.000
Second threshold (value)	10.411	9.313	9.341			
99% CI lower bound	10.175	9.294	9.278			
99% CI upper bound	10.470	9.408	9.408			
Bootstrap p-value	0.072	0.024	0.070			
Wald equal. coeff. reg. 1/2 (p)	0.0333	0.0912	0.0868	0.1069	0.0010	0.0021
Wald equal. coeff. reg. 2/3 (p)	0.0044	0.0009	0.0033			
Wald equal. coeff. reg. 1/3 (p)	0.5391	0.8448	0.9498			
Hansen-J (p)	-	-	-	0.489	0.605	0.595
Wu-Hausman Inc., reg.1 (p)	-	-	-	0.0564	0.9740	0.9680
Wu-Hausman Inc., reg.2 (p)	-	-	-	0.0994	0.1201	0.4244
Wu-Hausman Ann.I. (p)	-	-	-	0.1200	0.4279	0.4272
SSR no threshold	2.975	3.202	4.402	2.997	3.204	4.403
SSR one threshold	2.830	3.046	4.178	2.946	3.076	4.202
SSR two thresholds	2.745	2.942	4.062	-	-	-
R^2 within	0.232	0.229	0.200	0.176	0.194	0.172
N regime 1	162	164	166	325	317	317
N regime 2	155	153	151	65	73	73
N regime 3	73	73	73	-	-	-

Table 5: Economy-wide threshold estimates. Note: Cluster robust standard errors (Stock and Watson, 2008) adjusted for double-demeaning in parentheses. R^2 within refers to the R^2 within country and time. The threshold value of 9.307 refers to the (log) GDP per capita of the rest of South African Customs Union in 2006, 9.313 to Brazil in 1996, 9.341 to Uruguay in 2002, 10.411 to Germany in 1992, and 10.445 to Hong Kong in 2002.

bound (corresponding to the 99% confidence interval), and the p-value for testing the null hypothesis that the threshold does not exist. All thresholds reported in the table are statistically significant and well defined, as indicated by their rather narrow confidence intervals. Thus, not accounting for the piecewise-linear relationship between income and emissions would result in model misspecification and biased estimates.

The findings from the FE models in panel (1) point towards the existence of two thresholds in all emission inventories, while the IV-FE regressions in panel (2) result in one statistically significant threshold. In panel (1) the positive effect of income on all emission inventories increases in magnitude when moving from the first (low-) to the second (middle-income) regime and falls back again to its previous level when moving to the third (high-income) regime; the thresholds that separate these regimes correspond to log-income levels of 9.3 and 10.4, respectively. The income-elasticity in the middle-income regime is about one percentage point higher than in the other two regimes; this difference is statistically significant (as indicated by the Wald tests in the middle part of the table).[30] The IV-FE regressions in panel (2) only capture the higher income threshold, after which the income elasticity of emissions decreases.[31] Compared to the FE results the income elasticities resulting from IV-FE specifications are higher for production inventories and rather similar for the final production and consumption inventories.[32]

Accounting for threshold effects in income per capita uncovers statistically significant effects of Annex I membership and trade openness, which have been insignificant in the linear regressions. Annex I membership reduces methane emissions contained in production, while it is connected to higher CH_4 embodied in final production and consumption. Moreover, the effects on final production and consumption inventories outweigh the reduction of emissions in territorial production inventories, what is consistent with the existence of methane leakage.[33] Our estimates for production inventories are close to those of Aichele and Felbermayr (2012) for CO_2, which indicate a reduction of production-based CO_2 emissions by about 7% as a result of the Kyoto commitment. However, Aichele and Felbermayr's results suggest that Annex I ratification tends to increase emissions embodied in imports, which compensates the effect on production inventories, such that there

[30] The difference between the first and the second regime is statistically significant at the 5% (production) or 10% level (final production and consumption), whereas the difference between the second and the third regime is highly statistically significant at the 1% level for all inventories.

[31] The income elasticity of CH_4 embodied in final production and consumption decreases by about one to one-and-a-half percentage points when moving to the high-income regime. For CH_4 production the difference between the two regimes is smaller and statistically insignificant.

[32] The Wu-Hausman test, reported in the bottom part of the table, rejects the null of exogeneity of income for the CH_4 production inventory but fails to reject the exogeneity of income for CH_4 embodied in final production and consumption at conventional significance levels.

[33] Only in the uninstrumented FE regressions the effect of Annex I membership on CH_4 production inventories is statistically insignificant.

is no significant effect of Annex I ratification on carbon consumption footprints. This contrasts with our findings that methane footprints have increased on average in Annex I member countries. Trade openness has a positive effect on CH_4 production inventories, what, together with the results for Annex I membership, points to the existence of methane leakage and the inability of the Kyoto Protocol to limit global methane emissions. Finally, fuel exports and urbanization remain significant drivers of final production inventories, with the same sign as in linear models. Urbanization turns to significantly increase CH_4 emissions embodied in consumption.

Altogether, our results provide evidence for an adverse effect of economic growth on methane emissions. Yet, there is relative decoupling between economic development and emissions growth—a one-percent increase in per capita income is connected to a rise of emissions of less than one percent. The effect of economic growth on emissions is likely to worsen when moving from lower to middle levels of development, though it improves as countries reach higher levels of income. While the difference between the regime-dependent income elasticities is statistically significant, it is of rather low magnitude and only accounts for approximately one percentage point. Furthermore, the effects of trade openness and the ratification of the Annex I of the Kyoto Protocol are consistent with the existence of methane leakage. These findings support the view that the Kyoto Protocol did not introduce mechanisms to change the behavior of the countries bound by emission targets after signing its Annex I (Barret, 2008), and confirm that the enforcement of compliance with these targets has been problematic (see Nentjes and Klaassen, 2004, Hagem et al., 2005, Feaver and Durrant, 2008, Aichele and Felbermayr, 2012).

In order to draw conclusions concerning the mechanisms through which economic growth affects methane emissions, we have to account for the heterogeneity in the processes that generate methane as shown in our descriptive analysis. The sectors that are responsible for emissions at different stages of the supply chain differ in the scope for mitigation, which is determined by the existence of cleaner alternatives to current (dirty) inputs, the degree of input substitutability, and the potential to develop new technologies (see Acemoglu et al., 2012). At a macroeconomic level, sectoral shifts that are associated with economic development catalyze some of the effects of income on aggregate methane emissions.[34] Thus, we carry out our analysis at the sectoral level to derive information on the potential impact of economic growth and other factors on methane emissions in specific sectors, and

[34] Structural (sectoral) transformation is associated with economic development—value-added and labor shares of agriculture decrease, manufacturing shares show a hump-shaped relationship with economic growth, and services shares increase. Consumption measures show similar patterns (Herrendorf et al., 2013).

to shed light on the environmental effects of long-term shifts in the sectoral composition of production and consumption patterns.[35]

4.2 Sectoral results

Tables 6 to 8 present the results of the sectoral IV-FE threshold estimations for the three emission inventories, and report the contribution of each of the seven sectors to total emissions.[36] Looking first at the sector shares (% of total CH_4), methane emissions from production inventories are primarily concentrated in the livestock, energy, and public administration (mainly waste management) sectors, which together amount to 80% of total emissions. In final production and consumption inventories, methane is more evenly spread across sectors and these three sectors only account for about 50% of total emissions.

The sectoral regressions provide evidence for the existence of non-linearities in the relationship between income and CH_4 emissions per capita for most of the 21 sector–inventory combinations: 15 sector–inventory combinations are characterized by a piecewise-linear relationship, in one case there is evidence for a polynomial relationship, and in five cases we fail to find non-linearities.[37]

The analysis of the functional form of income elasticities at a sectoral level offers an explanation for the economy-wide non-linear patterns found. The economy-wide results stem from a mix of linear and threshold models at the sectoral level. The livestock sector, as well as the transport sector for production inventories, seem to govern the threshold found for national emissions at a log-income level of 10.4—once this threshold is exceeded, relative decoupling between emissions and income per capita increases in these sectors.[38] The energy, manufacturing, and public administration (mainly waste management) sectors mainly determine the threshold effect found economy-wide at a log-income level of 9.3;

[35] The time dimension of our global emissions dataset is restricted to the 1997–2011 period, which leaves relatively little time variation to exploit in the FE estimates. As a result, our estimates might not capture the implications of structural change on emissions to full extent. The inclusion of sectoral value added shares in our FE regressions mainly results in insignificant coefficients due to the rather low variability over the time period observed.

[36] Like before, we only include the baseline controls and statistically significant regressors in the models. More specifically, we include all regressors that are statistically significant in the linear IV-FE specifications (see Tables C.4 to C.6 in Appendix C). To determine statistically significant regressors, we follow a general-to-specific approach—we start with a model including the full set of regressors and consecutively drop statistically insignificant regressors. See also Tables C.7 to C.13 in Appendix C for further details.

[37] We find a linear relationship between income and CH_4 emissions in agriculture for final production, and in the service and transport sectors for final production and consumption inventories. An inverse-U relationship is present in the transport sector for territorial production inventories. All other sectors are best characterized through a piecewise-linear relationship between income and emissions per capita.

[38] For public administration we find a statistically significant threshold at a log-income level of about 10.4 after which the income elasticity of emissions is lower for final production inventories. Yet, the difference between the income elasticities of the two regimes is not statistically significant.

	Dependent variable: CH$_4$ embodied in production (IV-FE specifications) in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH$_4$)	9.38%	34.76%	25.12%	3.89%	0.85%	6.13%	19.88%
ln(Income), reg. 1	0.213	0.025	0.690 **	0.453 **	-0.912	14.984**	0.355 **
	(0.222)	(0.141)	(0.299)	(0.195)	(0.615)	(7.576)	(0.166)
ln(Income), reg. 2	0.257	0.011	0.733 **	0.515 ***	-0.817		0.375 **
	(0.213)	(0.147)	(0.298)	(0.185)	(0.610)		(0.165)
ln(Income), squared						-0.773*	
						(0.427)	
Annex I	0.085	0.106	-0.356 **	0.124	0.699 **	-0.527	-0.211 ***
	(0.148)	(0.212)	(0.142)	(0.143)	(0.317)	(0.489)	(0.071)
Openness	0.242 ***	0.286	0.338 **	0.173 *	-0.405	0.297	0.031
	(0.080)	(0.274)	(0.149)	(0.102)	(0.344)	(0.311)	(0.050)
Food exports				1.144 *			
				(0.611)			
Fossil rents				-1.739 *			
				(1.008)			
Polity IV				-0.019 **			
				(0.009)			
HDI medium					1.040 **		
					(0.470)		
HDI high					1.513 **		
					(0.594)		
HDI very high					1.671 **		
					(0.649)		
Threshold (value)	8.887	10.382	8.787	8.398	8.635	-	9.338
99% CI lower bound	8.545	8.051	8.762	8.281	8.051	-	9.294
99% CI upper bound	8.918	10.483	8.850	8.528	10.483	-	9.436
Bootstrap p-value	0.002	0.006	0.000	0.014	0.020	-	0.004
Wald eqal. coeff.							
reg 1/2 (p)	0.1096	0.1378	0.0000	0.0225	0.0310	-	0.0000
Turning point	-	-	-	-	-	9.695	-
U-test (p)	-	-	-	-	-	0.119	-
Hansen-J (p)	0.572	0.144	0.206	0.554	0.838	0.334	0.528
Wu-Hausman							
Inc., reg.1 (p)[a]	0.1070	0.4811	0.8806	0.2006	0.5525	0.9685	0.6435
Inc., reg.2 (p)[a]	0.7944	0.8104	0.2052	0.4435	0.0207	0.9265	0.5846
Ann.I. (p)	0.8698	0.8642	0.0704	0.1703	0.1456	0.2082	0.0180
SSE no threshold	41.098	73.430	33.871	39.002	242.741	183.603	6.040
SSE one threshold	39.833	71.662	32.247	38.308	239.699	-	5.798
R^2 within[b]	0.034	0.036	0.122	0.114	0.029	0.214	0.117
N regime 1	115	310	108	79	92	390	165
N regime 2	275	80	282	311	298	-	225

Table 6: Sectoral threshold results for CH$_4$ embodied in production. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2 in the Appendix). The U-Test refers to the test for a U-shaped relationship by Lind and Mehlum (2010). [a] The Wu-Hausman test for Inc., reg.1 and reg.2 refer to the income and squared income term, respectively, for the polynomial model. [b] R^2 within stands for R^2 within country and time for the threshold models and for the R^2 within country for the polynomial model. The threshold value of 8.887 refers to the (log) GDP per capita of the rest of Andean Pact in 2006, 10.382 to Hong Kong in 1996, 8.787 to the rest of South America in 1996, 8.398 to Morocco in 1999, 8.635 to Sri Lanka in 2002, and 9.338 to Slovakia in 1992.

	Dependent variable: CH_4 embodied in final prod. (IV-FE specifications) in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH_4)	13.23%	23.83%	4.97%	15.36%	14.19%	4.65%	23.77%
ln(Income), reg. 1	0.342	-0.038	0.041	0.587 **	0.115	1.109***	0.395 ***
	(0.251)	(0.165)	(0.389)	(0.255)	(0.341)	(0.385)	(0.097)
ln(Income), reg. 2		-0.058	0.063	0.664 ***			0.390 ***
		(0.166)	(0.380)	(0.224)			(0.099)
Annex I	0.589***	-0.100	-0.304 *	-0.091	0.267**	0.491**	-0.107
	(0.164)	(0.110)	(0.169)	(0.124)	(0.128)	(0.203)	(0.079)
Openness	-0.280*	0.110 *	0.023	0.294 ***	-0.049	0.087	0.130
	(0.162)	(0.059)	(0.212)	(0.104)	(0.149)	(0.197)	(0.092)
Food exports							1.164 ***
							(0.279)
Fuel exports		0.662 ***	-1.310 **		-0.707*	-1.902**	
		(0.241)	(0.574)		(0.377)	(0.780)	
HDI medium	0.192				0.224**		
	(0.121)				(0.100)		
HDI high	0.318*				0.388***		
	(0.193)				(0.146)		
HDI very high	0.255				0.288		
	(0.243)				(0.193)		
Threshold (value)	-	10.348	9.436	8.052	-	-	10.469
99% CI lower bound	-	10.247	8.051	8.052	-	-	10.355
99% CI upper bound	-	10.483	10.483	8.052	-	-	10.483
Bootstrap p-value	-	0.002	0.036	0.000	-	-	0.002
Wald equal. coeff.							
reg 1/2 (p)	-	0.0013	0.2132	0.1114	-	-	0.3993
Hansen-J (p)	0.553	0.483	0.300	0.563	0.280	0.115	0.556
Wu-Hausman							
Inc., reg.1 (p)	0.1904	0.1432	0.3381	0.5558	0.4967	0.1635	0.1672
Inc., reg.2 (p)	-	0.1172	0.3641	0.0262	-	-	0.4751
Ann.I. (p)	0.1756	0.4687	0.3932	0.2925	0.0779	0.1768	0.0708
SSE no threshold	28.289	18.011	39.555	28.482	18.344	48.122	6.204
SSE one threshold	-	17.233	38.937	26.592	-	-	6.074
R^2 within[a]	0.157	0.098	0.074	0.149	0.282	0.319	0.127
N regime 1	390	298	180	59	390	390	330
N regime 2	-	92	210	331	-	-	60

Table 7: Sectoral threshold results for CH_4 embodied in final production. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2 in the Appendix). [a] R^2 within stands for R^2 within country and time for the threshold models and for the R^2 within country for the linear models. The threshold value of 10.348 refers to the (log) GDP per capita of Belgium in 1992, 9.436 to Brazil in 2006, 8.052 to the rest of South Asia in 1996, and 10.469 to Sweden in 1999.

	Dependent variable: CH_4 embodied in consumption (IV-FE specifications) in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH_4)	13.23%	23.83%	4.97%	15.36%	14.19%	4.65%	23.77%
ln(Income), reg. 1	0.431 **	0.012	0.074	0.602 **	0.136	1.411***	0.215 *
	(0.182)	(0.195)	(0.466)	(0.265)	(0.349)	(0.414)	(0.115)
ln(Income), reg. 2	0.449 **	-0.013	0.095	0.687 ***			0.244 **
	(0.182)	(0.198)	(0.466)	(0.234)			(0.111)
Annex I	0.612 ***	-0.146	0.025	-0.027	0.285**	0.574***	-0.229 ***
	(0.134)	(0.145)	(0.209)	(0.100)	(0.123)	(0.179)	(0.086)
Openness	-0.027	0.036	-0.031	0.029	-0.055	-0.048	0.123
	(0.110)	(0.092)	(0.239)	(0.148)	(0.169)	(0.202)	(0.096)
Food exports							1.134 ***
							(0.304)
Fuel exports		0.571 **	-2.133 ***				
		(0.277)	(0.810)				
ln(Pop. density)			1.591 **				
			(0.731)				
Polity IV							0.006 **
							(0.003)
HDI medium	0.184		0.394 *		0.265***		
	(0.124)		(0.232)		(0.102)		
HDI high	0.397 **		0.623 **		0.433***		
	(0.188)		(0.300)		(0.149)		
HDI very high	0.337		0.669 **		0.375**		
	(0.219)		(0.326)		(0.190)		
Threshold (value)	10.176	10.348	9.308	8.052	-	-	9.461
99% CI lower bound	8.051	10.282	8.051	8.052	-	-	9.453
99% CI upper bound	10.483	10.369	10.483	8.052	-	-	9.570
Bootstrap p-value	0.008	0.000	0.066	0.000	-	-	0.004
Wald equal. coeff.							
reg. 1/2 (p)	0.0049	0.0094	0.1425	0.0756	-	-	0.0010
Hansen-J (p)	0.576	0.275	0.217	0.433	0.290	0.090	0.517
Wu-Hausman							
Inc., reg.1 (p)	0.6448	0.4998	0.4687	0.3268	0.4002	0.2597	0.2413
Inc., reg.2 (p)	0.8319	0.3804	0.2897	0.6712	-	-	0.2046
Ann.I. (p)	0.0688	0.4038	0.6007	0.7628	0.0835	0.0939	0.0239
SSE no threshold	22.679	19.908	47.855	20.996	18.430	42.675	9.230
SSE one threshold	21.793	17.892	47.440	19.726	-	-	8.904
R2 within[a]	0.173	0.110	0.165	0.199	0.254	0.306	0.117
N regime 1	274	298	163	59	390	390	184
N regime 2	116	92	227	331	-	-	206

Table 8: Sectoral threshold results for CH_4 embodied in consumption. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2 in the Appendix). [a] R^2 within stands for R^2 within country and time for the threshold models and for the R^2 within country for the linear models. The threshold value of 10.176 refers to the (log) GDP per capita of Spain in 1996, 10.348 to Belgium in 1992, 9.308 to Brazil in 1999, 8.052 to the rest of South Asia in 1996, and 9.461 to Latvia in 2002.

in these sectors emissions per capita increase more strongly with economic growth once the threshold has been reached.[39] This pattern of sectoral composition in the threshold effects is consistent with the declining role of primary sectors and the rising importance of industrialization, which is accompanied by increased demand for energy, public sector services, and waste management in the course of economic development (see Kuznets, 1973, Herrendorf et al., 2013).

Examining the sectors in detail, for agriculture, economic growth does not significantly affect methane per capita derived from territorial and final production inventories, probably because production patterns are related to comparative advantage, which changes rather slowly over time. By contrast, emissions increase significantly with income per capita in consumption inventories, where also the income elasticity slightly increases after a threshold is reached. This is likely to be driven by the more intensive use of energy in processed agricultural goods, the sector with the largest share in total methane from consumption inventories among agriculture sectors. Like for methane derived from production in the agriculture sector, economic growth does not contribute significantly to emissions from the livestock and services sectors in any inventory.

The energy and manufacturing sectors show larger elasticities after a certain level of development is reached. Emissions embodied in energy production expand with income per capita, with rather high income elasticities of about 0.7. This effect is mainly determined by the role of energy as a key intermediate input in production processes. However, it becomes statistically insignificant in final production and consumption inventories. Turning to manufactures, income growth significantly affects methane per capita in all inventories. The income elasticity is rather high, between 0.5 and 0.7, and increases as we move downstream through the supply chain.

Emissions embodied in transport increase with income, too. For production inventories, the income elasticity follows an inverse-U shape, with a turning point corresponding to a log-income level of 9.7. For final production and consumption inventories, income elasticities are larger than one, pointing to coupling between income and emissions per capita. Finally, economic development results also in higher emissions from public sector services. The income-elasticity in this sector is moderate, below 0.4, and increases slightly in the second regime.[40] Notably, for production inventories, methane emissions are mostly released by waste management.

[39] For CH_4 production inventories, also the agriculture and services sectors influence this pattern to some extent. Still, the increase in the income-elasticity of emissions in the agriculture sector is not statistically significant, and the threshold in the services sector is not very narrowly defined. The same is true to some extent for agriculture for final production inventories; also there the confidence interval of the threshold covers the whole income range.

[40] The income elasticity of emissions from final production decreases when moving from the first to the second regime, at a higher threshold value.

Our sectoral findings suggest that more than 40% of total methane emissions are not significantly affected by income per capita.[41] Notwithstanding, economic development will also induce shifts in the sectoral composition of production and consumption patterns. In early stages of development countries are likely to experience industrialization and an expansion of the manufacturing sector, while primary sectors contract. Based on our sectoral results, this would increase the income elasticity of methane emissions per capita, because the manufacturing sector is characterized by a relatively high income elasticity. In later stages of economic development countries are likely to experience a relative expansion of the services sector (tertiarization), what may result in a decrease in the income elasticity of emissions economy-wide, since relative decoupling is larger in the services sector than in manufactures. Yet, the demand for energy, and the importance of transport and the public sector (including waste management) will also increase with economic development, and, given their large income elasticities relative to services, will tend to raise per capita methane releases. Thus, although the net effect of changes in the sectoral composition is a priori ambiguous, our empirical results indicate that structural transformation tends to be connected to more polluting emission patterns.

The ratification of the Annex I of the Kyoto Protocol significantly affects 5 of the sectors analyzed. On the (territorial) production side, Annex I membership has been associated with a reduction of emissions per capita in the energy and public administration sectors, which together account for 45% of total emissions from production. Nevertheless, it has increased emissions in the service sector, even though this sector has experienced considerable efficiency gains and even reduced its total methane emissions in high income countries, which are roughly 90% of Annex I signatories (see Figure 3 in subection 2.2). Thus, this result seems driven by the tertiarization of these economies. When looking at final production and consumption inventories, Annex-I ratification has been connected to higher emissions in the agriculture, services, and transport sectors, pointing towards the existence of methane leakage. Interestingly, the significant emission-reduction effect of Annex-I ratification disappears in the energy sector when looking at CH_4 embodied in consumption, likely as a result of energy imports from other non-Annex I countries. This pattern resembles the findings of Aichele and Felbermayr (2012) regarding the effect of the Kyoto Protocol on total CO_2 emissions.

The role of international trade continues to support the hypothesis of methane leakage effects on the supply side at the sectoral level, though it is restricted to primary and secondary (including energy) sectors. Trade openness is mainly connected to larger emis-

[41] For production inventories, 45% of emissions is not significantly affected by income per capita (i.e. emissions from agriculture, livestock, and services), while for final production inventories, this share is 56% of emissions (i.e. agriculture, livestock, energy, and services). For consumption inventories the ratio is 43% of emissions (i.e. livestock, energy, and services).

sions in agriculture, energy and manufacturing for production inventories. Noteworthy, trade also appears significant in some sectors for final production inventories—it increases emissions per capita in livestock and manufacturing, whereas it tends to lower emissions per capita in the agriculture sector. Trade remains insignificant at the sectoral level in consumption inventories.

The share of food products in total exports is not significantly related to changes in emissions from the primary sectors. This challenges Jorgenson and Birkholz's (2010) conclusions that an economy-wide effect of increasing emissions per capita may be explained by competitive pressures on food exporters to lower their environmental standards for food production, or that countries with some orientation to food exports specialize in relatively more CH_4 intensive agricultural products. The share of food in total exports increases methane per capita embodied in production of manufactures and in final production and consumption of public sector services. Noteworthy, fuel exports decrease emissions embodied in the final production of energy, services and transport, what seems to result from the lower specialization of fuel exporters in final products. In addition, fuel exporters in our sample are characterized by a larger demand for consumption products from the livestock sector, while their consumption share of energy is smaller, probably affected by their degree of development. Related to this, higher fossil rents as a share of GDP are connected to lower emissions embodied in manufacturing (production inventories), reflecting the sectoral composition of countries specialized in fossil energy production.

Interestingly, population density is only significant in one sector. Specifically, higher population density resulting from population growth increases the demand for energy and, thus, methane embodied in energy consumption. Moreover, urbanization is not significant anymore in any sector. This indicates that population density and urbanization capture effects associated with economic growth in economy-wide regressions. These effects are not found at a sectoral level, where they seem to be better captured by other variables that proxy socio-economic development (e.g., income per capita and HDI dummies).

Democratic institutions only appear significant in two sectors and inventories. More democratic institutions are associated with lower levels of emissions per capita in manufactures in production inventories. This partially counteracts the effect of the Kyoto Protocol dummy in more advanced democracies. By contrast, democratic institutions tend to increase emissions per capita in public sector services in consumption inventories, as a consequence of the larger demand for government services in more democratic political systems. Finally, higher stages of socio-economic development, as indicated by the HDI-group dummies, tend to increase methane releases in various sectors.[42] All these effects question the idea that preferences for cleaner environment may lower methane emissions in democratic and more developed countries.

5 Conclusions

We put forward a global panel dataset of national inventories of methane emissions embodied in territorial production, final production, and consumption activities. Our dataset reveals several stylized facts of anthropogenic methane emissions. Global methane emissions are quantitatively important. They are equivalent to between 25% and 84% of CO_2 emissions from fossil fuel combustion, depending on the time frame used to compute the equivalence, and have increased about 25% during 1997–2011. The bulk of emissions is attributable to developing countries, but still high-income countries have been net-importers of emissions. Economic growth and expanding population have been responsible for the increase in emissions from developing countries, whereas methane efficiency gains only partially counteracted these effects.

International, coordinated action on climate change mainly concerns the determination of property rights on responsibilities for damage, and costs and rents from policies. There are transaction costs that increase the costs or decrease the probability of reaching an agreement for multilateral cooperation (Libecap, 2014). Atmospheric methane emissions are an important global pollutant which shows negative (global) externalities and poses several challenges to coordinated action to mitigate or abate it. Effective international cooperation to mitigate global negative externalities, such as methane emissions, will take place when transaction costs are overcome. In this sense, the information contained in our dataset contributes to reduce transaction costs associated with scientific uncertainty regarding the causes of global methane pollution at a regional level and transaction costs associated with enforcement of policies. Therefore, it can be valuable for the design and enforcement of policy instruments, and for evaluation of potential inter-sectoral and international spillovers of the environmental policies applied.

Our econometric analysis confirms a positive relationship between economic growth and methane emissions for all three emission inventories. This relationship is highly statistically significant and quantitatively important, and points to the existence of relative decoupling—meaning that a one-percent increase in per capita income leads to a rise of emissions of less than one percent, though overall emissions still rise with income.

[42] HDI dummies pick up effects of economic development that cannot be attributed to the income per capita. We test for this by deleting HDI groups from the estimations. As a result, income elasticities increase or become significant (when they were not). Further details are available upon request.

Economy-wide, the relationship is non-linear, characterized by threshold effects. While the effect of economic growth on emissions is likely to worsen when moving from lower to middle levels of development, there is clear evidence for a threshold characterizing small efficiency gains at very high levels of development.

Although there is substantial heterogeneity in the functional form of the estimated income-elasticity at a sectoral level, most sectors show threshold effects. The mix of linear and threshold models found at the sectoral level offers an explanation to the non-linear patterns detected economy-wide. The energy, manufacturing, and public administration sectors mainly determine the rise in the income elasticity of CH_4 emissions when moving from lower-middle to upper-middle levels of income per capita in many sectors, while the livestock sector, as well as the transport sector for production inventories, govern the small efficiency gains captured by the threshold effect found at very high levels of development. Our sectoral findings also show that more than 40% of total methane emissions are not significantly affected by income per capita. Economic development will also induce sectoral composition shifts in production and consumption patterns. Despite the net effect of sectoral transformation being a priori ambiguous, our results suggest that sectoral shifts accompanying development may increase emissions.

Preferences for cleaner environment do not seem to lower methane emissions in democratic and more developed countries. Moreover, the Kyoto Protocol has been largely ineffective in the mitigation of anthropogenic CH_4 emissions. While there is some evidence for a decrease in emissions derived from production activities in Annex I countries, mainly resulting from the reduction of emissions in the energy and public administration sectors, methane releases embodied in final consumption in these countries are significantly larger than in their non-Annex I counterparts. These results render support to the view that the targets and enforcement mechanisms of the Kyoto Protocol were ill-designed (see, Nentjes and Klaassen, 2004, Hagem et al., 2005, Barret, 2008, Feaver and Durrant, 2008). Additionally, international trade has a positive effect on emissions on the production side, mostly restricted to primary and secondary sectors including energy. The existence of methane leakage cannot be rejected.

The sectoral heterogeneity found may introduce additional transaction costs associated with design and implementation of both international agreements and national policies, which find their ground in the existing asymmetries in economic structures and preferences across and within nations (Libecap, 2014). The larger the heterogeneity in economic structures or preferences, the lower the probability of international cooperation to cope with the problem of global negative externalities. Asymmetries across nations deepen as a result of increasing divergence in the sectoral composition of their economies at different stages of economic development or as a consequence of economic specialization. Within nations, as methane releases are concentrated in few sectors, sectoral specificities of pollution push asymmetric preferences concerning mitigation. This influences the positions negotiators will exhibit in international agreements and affects the willingness to implement national policies, especially if the sectors affected by the new policies are able to form lobbies.

The rapid increase that methane emissions have recently experienced, together with their high warming potential, highlight the necessity to start a strong policy strategy to mitigate and abate atmospheric concentrations of methane. The carbon-based climate change paradigm has been connected to the responsibility for CO_2 concentrations which have been reached after decades or centuries of emissions. Given the strong warming potential of methane in the beginning of its atmospheric life, increasing methane emissions may change this paradigm, making global warming more dependent on current rather than past patterns of pollution. This calls for efficient mechanisms to attribute the responsibility for emissions to all economies, regardless of whether they are responsible for past levels of methane concentrations.

Notwithstanding, as our research underlines, there are some factors that may complicate the design and implementation of environmental instruments against pollution from methane emissions. There is a remarkable diversity in the anthropogenic processes that produce CH_4 emissions, and many sectors reveal considerable relative decoupling with respect to economic development. For climate change mitigation to be effective, national instruments must take into account the diverse nature of the processes that are responsible for emissions and the existence of international trade linkages. National environmental policies must take those sectoral specificities into consideration and take place at the sectoral level with specific designs. More comprehensive, global agreements on policy instruments to combat global warming must also address these difficulties and sectoral particularities.

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Online Appendices

A Construction of national emission inventories

We first generate our national (standard, territorial) production-based emission inventories. For that purpose, we map methane emissions from several sources to the 57 sectors of the 78 regions covered.[43] These inventories constitute the standard measure of national CH_4 emissions relevant for multilateral agreements on emissions reduction such as the Kyoto Protocol. We then develop inventories of CH_4 emissions embodied in both final production and final consumption activities using MRIO techniques.

A.1 Construction of territorial production inventories

In order to create a consistent panel of sectoral methane emissions inventories for the years 1997, 2001, 2004, 2007 and 2011, we modify and extend the methodology developed by the Global Trade Analysis Project (GTAP) to elaborate the methane data provided by the different "non-CO_2 Emissions database" releases (see Rose and Lee, 2008, Rose et al., 2010, Ahmed et al., 2014, Irfanoglu and van der Mensbrugghe, 2015).[44] Unfortunately, the GTAP CH_4 emissions data cannot be used in a panel framework, since the sources of raw data and/or the methodology for data construction differ across releases.[45]

Therefore, we construct our territorial production inventories, maintaining the sectoral disaggregation and countries present in GTAP data, ensuring consistency over time. For the years 2001, 2004, 2007 and 2011, we match methane emissions categories from the FAOSTAT (2014) and EDGAR (2011) databases directly to the 57 sectors where possible,

[43] An overview of the regions and sectors covered is available in Table B.1 and B.2, respectively, in Appendix B. We maintained the highest degree of sectoral and regional disaggregation in order to minimize aggregation bias, while keeping consistency over time. Therefore, we were able to compute inventories at 57 sectors, which is equal to GTAP sectoral disaggregation, and 78 regions (66 countries and 12 regions) which is the minimum regional disaggregation of the raw data used (of GTAP release for 1997).

[44] These releases include methane emissions, among other GHGs, for the years 2001, 2004, 2007 and 2011, disaggregated to 57 economic sectors. We extend the time dimension backwards to 1997.

[45] The 2001 release was constructed in cooperation between GTAP and the US Environmental Protection Agency, resulting in a highly disaggregated database of GHG emissions linked to economic activity (see Rose et al., 2007, Rose and Lee, 2008); this undertaking has not been repeated since then. Thus, GTAP applied growth rates of detailed GHG emission categories provided by the EDGAR (2011, non-agricultural activities) and FAOSTAT (2014, agricultural activities) datasets on their 2001 data to extrapolate it to 2004 and 2007 (Ahmed et al., 2014). The only exceptions were the GTAP sectors "mineral production", "manufactures n.e.c". and "paper products and publishing". For these sectors no EDGAR data was available. Ahmed et al. (2014) thus extrapolate 2001 GTAP data of these sectors using an output growth approach. For the 2011 release GTAP changed methodology again and matched EDGAR (2011) and FAOSTAT (2014) data directly to sectors.

using the concordance tables provided by Irfanoglu and van der Mensbrugghe (2015).[46] All categories in the FAO and many in the EDGAR databases can be directly matched to a single sector, resulting in a direct match of about 75% of global emissions. We allocate the remaining 25%, which are EDGAR (2011) emission categories that can be matched to more than one sector, to our 57 sectors by using sector shares of emissions provided by GTAP. To be as precise as possible, we additionally incorporate GTAP information on whether emissions are caused by usage of endowments by industries, output and input usage of industries, or input usage of households, to the mapping process.[47] Finally, as the most recent methane emissions data provided by EDGAR is from 2010, we follow Irfanoglu and van der Mensbrugghe (2015) and extrapolate EDGAR data to 2011 by using average growth rates of CH_4 in the EDGAR categories between 2007 and 2010.

Additionally, we extend our dataset back to 1997. As for the other years we match FAO and EDGAR CH_4 emissions data directly to sectors where possible; for the remaining sectors we apply moving averages on the GTAP data from 2001–2011 to derive estimates for 1997. We then allocate the EDGAR emission categories among sectors using those shares.

This procedure results in a dataset of territorial CH_4 emissions for the years 1997, 2001, 2004, 2007 and 2011 disaggregated to 57 economic sectors. This inventory refers to emissions originated within national boundaries. We can further aggregate sectoral emissions, resulting in a balanced panel dataset of 390 observations, which correspond to national production (territorial based) CH_4 inventories.[48] In a next step we combine territorial sectoral emissions data with input-output and trade data provided by GTAP to calculate comparable final production and consumption based CH_4 inventories (i.e. CH_4 footprints).

[46] As noted by Kirschke et al. (2013), depending on the methodology used to measure atmospheric methane emissions, anthropogenic emissions dominate natural emissions (top-down methods) or are of a comparable size, though slightly below them (bottom-up estimates). Nevertheless, there is uncertainty associated to these measurements; for example, Schwietzke et al. (2016) report that the estimated contribution of total fuel methane emissions (defined as fossil fuel industry plus natural geological seepage) has been estimated between 15 and 22% of total methane emissions. However, the authors provided evidence based on a new isotope records database that (i) total fuel methane emissions may be 60 to 110% larger than current estimates; (ii) emissions from the fossil fuel industry may be 20 to 60% larger than in current inventories; and (iii) natural gas production emissions may have declined from 8 to 2% during 1985–2013.

[47] See Table B.3 for an overview of the sectors and the matching of FAO and EDGAR data. Unlike GTAP, we also match the sub-categories of FAO category "Burning Crop Residues" directly to single sectors. We split methane emissions captured by the EDGAR category "Other Industrial Non-Agricultural Sources CH_4" into "Other - Chemicals ", assigned to GTAP sector "chemical, rubber and plastic products (crp)", and "Other - Metals" assigned to GTAP sectors "ferrous metals (i_s)", "metals n.e.c (nfm)".

[48] We aggregate our data to the 66 countries and 12 regions present in the year 1997 to remain consistent over time.

A.2 From territorial production inventories to final production and consumption inventories

To construct the footprint measures for national CH_4 emissions, we implement MRIO techniques. We first combine input-output and trade data sourced from GTAP to construct a global intermediate input requirements matrix. Next, we create an environmentally extended MRIO table by scaling the global requirements matrix to CH_4 emissions and calculate the environmentally extended Leontief-inverse matrix, which collects the direct and indirect CH_4 requirements for a given unit of output for each sector in each region. We finally derive the final production and consumption based national inventories.

Let us define the vector of sectoral gross outputs in region i as $x_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,s})'$, where its dimension s is the number of sectors defined in the economy (57 in our case). We define the exporter region as r and the importer region as p, such that $r, p \subseteq [1, n]$, where n stands for the total number of regions considered (78 in our case). The gross output of a sector is used as intermediate input for another sector or as final demand. The companion vector of sectoral gross output for all the n regions is equal to the intermediates required as inputs from all sectors in all regions plus final demands from all regions. That is,

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \cdots & A_{nn} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{pmatrix} + \begin{pmatrix} y_{11} & y_{21} & \cdots & y_{n1} \\ y_{12} & y_{22} & \cdots & y_{n2} \\ y_{13} & y_{23} & \cdots & y_{n3} \\ \vdots & \vdots & \ddots & \vdots \\ y_{1n} & y_{2n} & \cdots & y_{nn} \end{pmatrix} l \,, \qquad (3)$$

where $(x_1, x_2, x_3, \ldots, x_n)'$ is the companion vector of sectoral gross output for all the n regions. Each A_{rp} is the $s \times s$ matrix of trade in intermediates from region r to region p (which refers to domestic flows wherever $r = p$). We follow input–output conventions and define flows across rows as sales and flows down the columns as expenditures. The components of the A_{rp} matrices are normalized to sectoral gross output. Thus, each element a_{kj} in A_{rp} denotes the direct inputs from sector k in region r needed for a sector j in region p to produce one unit of output, where $k, j \subseteq [1, s]$. We calculate the MRIO tables for each year from input–output, trade, and demand data provided by the GTAP database following Peters et al. (2011).[49] The matrix with elements A_{rp}, which we cast

[49] Kanemoto et al. (2012) discuss several methods to compute methane emissions embodied in trade. A broader discussion of MRIO methodologies can be found in Davis and Caldeira (2010), Davis et al. (2011), and Peters (2008), among others.

A, is the MRIO matrix that collects all the intermediate input requirements of all sectors in all regions. It is of dimension $(n \cdot s) \times (n \cdot s)$.

Each element y_{pr} in the last matrix (which we name Y) appearing on the right-hand side of equation (3) denotes the final demand in region p for products from region r, being $y_{pr} = (y_{pr,1}, y_{pr,2}, \ldots, y_{pr,s})'$ a column vector of dimension s where each element $y_{pr,z}$ is the final demand in region p for products from sector z in region r. The vector l is an all-ones column vector of dimension n. The product of the matrix of final demands by the vector l, Yl, results in the column vector of total final demands y.

To take into account the indirect flows of CH_4 emissions through global supply chains, we first solve the expression above $x = Ax + y$ for the companion vector of gross outputs such that $x = (I - A)^{-1}y$. The matrix $(I - A)^{-1}$ is the Leontief-inverse matrix, where I is the identity matrix. The Leontief-inverse in the multi-regional framework is the matrix of total (direct and indirect) unit input requirements of each sector in each region for intermediates from each sector in each region. The columns of the Leontief-inverse matrix show the unit input requirements (direct and indirect) from all other producers (rows), generated by one unit of output. Denoting its sub-matrices as $(I - A)^{-1}_{rp}$, each element $(i - a)^{-1}_{kj}$ in $(I - A)^{-1}_{rp}$ contains the direct and indirect inputs needed from sector k in country r to produce one unit of output in sector j in country p.

Finally, we compute the final (embodied) production and final consumption emissions inventories at a national level. We can define the flux of CH_4 emissions embodied in final production of region r, $f^o_r = (f^o_{r1}, f^o_{r2}, \ldots, f^o_{rn})$, where the components of f^o_r (i.e., $f^o_{r1}, \ldots, f^o_{rn}$) show the final production of the region r using intermediates from regions 1 to n embodied in final production of region r. We also define the flux of CH_4 emissions embodied in final consumption of region r, $f^c_r = (f^c_{1r}, f^c_{2r}, \ldots, f^c_{nr})$, where the components of f^c_r (i.e., $f^c_{1r}, \ldots, f^c_{nr}$) show the final consumption of the region r of intermediates from regions 1 to n embodied in final demand of region r. Therefore,

$$f^o_r = E\,(I - A)^{-1}\,o_r\ , \tag{4}$$

$$f^c_r = E\,(I - A)^{-1}\,c_r\ , \tag{5}$$

In expressions (4) and (5), the Leontief-inverse matrix is rescaled by the diagonal matrix E of dimension $(n \cdot s) \times (n \cdot s)$ of regional emission-intensities. For that purpose, we define the vector of sectoral emission-intensities in region i as $e_i = (e_{i,1}, e_{i,2}, \ldots, e_{i,s})$ such that each element is calculated as the ratio of CH_4 emissions per gross output of the corresponding sector $(x_{i,s})$. The vector of elements of the main diagonal of E, $e = (e_1, e_2, \ldots, e_n)$, stacks all the n regional emission-intensities e_i. Thus, the term $E\,(I-A)^{-1}$ is the matrix of total (direct and indirect) embodied methane intensities of each sector in each region; it is of dimension $(n \cdot s) \times (n \cdot s)$. The vectors o_r and c_r are the column-vectors of final production from region r, $o'_r = (y'_{r1},\, y'_{r2},\, y'_{r3},\, \dots,\, y'_{rn})$, and final consumption of region r, $c'_r = (y'_{1r},\, y'_{2r},\, y'_{3r},\, \dots,\, y'_{nr})$. Both have dimension $(n \cdot s)$.[50]

Expression (4) describes the flux of emissions embodied in final production of region r. Methane emissions are a function of the bundle of intermediates from all sectors and regions that are used in the supply chain, determined by the Leonfief inverse, $(I-A)^{-1}$, and the methane intensities, collected in E. As mentioned above, the components of f^o_r (i.e., $f^o_{r1}, \dots, f^o_{rn}$) show the final production of the region r using intermediates from regions 1 to n embodied in final production of region r. Furthermore, the sum of the components of f^o_r across providers of intermediates, $\phi^o_r = \sum_p f^o_{rp}$, shows the total (direct and indirect) CH_4 emissions embodied in final production of region r. We can finally define a vector of components ϕ^o_r, where $r \subseteq [1, n]$, which constitutes our national final (embodied) production emissions inventories.

Analogously, equation (5) describes the flux of emissions embodied in final consumption of region r. Methane emissions are a function of the bundle of final goods (incorporating intermediates) from all sectors and regions that are embodied in final demand of region r, determined by the Leontief-inverse, $(I-A)^{-1}$, and the methane intensities, collected in E. As mentioned above, the components of f^c_r (i.e., $f^c_{1r}, \dots, f^c_{nr}$) show the final consumption of the region r of intermediates from regions 1 to n embodied in final demand of region r. Furthermore, the sum of the elements of f^c_r across providers of final goods, $\phi^c_r = \sum_p f^o_{pr}$, shows the total (direct and indirect) CH_4 emissions embodied in final consumption of region r. We can also define a vector of components ϕ^c_r, where $r \subseteq [1, n]$, which constitutes our national consumption emissions inventories.

[50] Note that y_{rp} in o_r denotes exports of final production from region r to region p, while y_{pr} in c_r denotes imports of final demand by region r of production from region p; y_{rr} denotes domestic final demand. As mentioned above, both y_{rp} and y_{pr} are row vectors of dimension s.

B Data appendix

Aggregate	Countries and regions included
	Single Countries and Regions:
The 66 single countries and regions	Albania, Argentina, Australia, Austria, Belgium, Bangladesh, Bulgaria, Brazil, Botswana, Canada, Chile, China, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malawi, Malaysia, Malta, Mexico, Morocco, Mozambique, Netherlands, New Zealand, Peru, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovakia, Slovenia, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zambia, Zimbabwe
	The 12 Composite Regions:
Rest of Andean Pact	Bolivia and Equador
Central America, Caribbean	Anguila, Antigua & Barbados, Aruba, Bahamas, Barbados Belize, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago and Virgin Islands (GB)
Rest of EFTA	Iceland, Liechtenstein and Norway
Rest of Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyszstan, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan
Middle East	Bahrain, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Rep., United Arab Emirates and Yemen
Rest of North Africa	Algeria, Egypt, Libyan Arab Jamahiriya and Tunisia
Other Southern Africa	Angola and Mauritius
Rest of South African Customs Union	Lesotho, Namibia, South Africa and Swaziland
Rest of South America	Guyana, Paraguay and Suriname
Rest of South Asia (RSA)	Bhutan, Maldives, Nepal and Pakistan
Rest of Sub-Saharan Africa (SSA)	Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Magagascar, Mali, Mauritania, Mayotte, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Togo and Congo (DPR)
Rest of World	Afghanistan, Albania, Andorra, Bermuda, Bosnia and Herzegowina, Brunei, Cambodia, Faroe Islands, Fiji, French Polynesia, Gibraltar, Greenland, Guadeloupe, Kiribati, Lao (PDR), Macau, Macedonia (former Yugoslav Republic of), Marshall Islands, Micronesia, Monaco, Mongolia, Myanmar, Nauru, New Caledonia, Korea (DPR), Papua New Guinea, San Marino, Solomon Islands, Tonga, Tuvalu, Vanuatu, Western Samoa, Rest of former Yugoslavia

Table B.1: Countries and GTAP composite regions in the database. Note: Computations were performed using the regional aggregation of GTAP 5. Countries which show up in later GTAP databases but not in GTAP 5 were assigned to the Rest of World composite region. Those countries are too small to change results, however. They are mainly small islands states or territories belonging to the jurisdiction of another country, which show up in one of the later composite regions (Wallis and Fortuna, for example). The only notable exceptions are Timor-Leste and Greenland.

Final Dem. Sector	GTAP Sectors
Agriculture (agr.)	Paddy rice (pdr); Wheat (wht); Cereal grains nec (gro); Vegetables, fruit, nuts (v_f); Oil seeds (ost); Sugar cane, sugar beet (c_b); Plant-based fibers (pfb); Crops nec (ocr); Forestry (frs); Fishing (fsh); Sugar (sgr); Food products nec (ofd); Beverages and tobacco products (b_t); Vegetable oils and fats (v_f); Processed rice (pcr);
Livestock (liv.)	Cattle, sheep, goats, horses (ctl); Animal products nec (oap); Raw milk (rmk); Wool, silk-worm cocoons (wol); Meat: cattle, sheep, goats, horse (cmt); Meat products nec (omt); Dairy products (mil);
Manufacturing (mfc.)	Textiles (tex); Wearing apparel (wap); Leather products (lea); Wood products (lum); Paper products, publishing (ppp); Chemical, rubber, plastic products (crp); Mineral products nec (nmm); Ferrous metals (i_s); Metals nec (nfm); Metal products (fmp); Motor vehicles and parts (mvh); Petroleum, coal products (p_c); Transport equipment nec (otn); Electronic equipment (ele); Machinery and equipment nec (ome); Manufactures nec (omf);
Transport (trn.)	Transport nec (otp); Sea transport (wtp); Air transport (atp);
Services (ser.)	Water utility services (wtr); Construction (cns); Trade and distribution (trd); Communication (cmn); Financial services nec (ofi); Insurance (isr); Business services nec (obs); Recreation and other services (ros); Dwellings (dwe);
Energy (egy.)	Coal (coa); Oil (oil); Gas (gas); Minerals nec (omn); Electricity (ely); Gas manufacture, distribution (gdt);
Public Administration (pub.)	Public Administration (osg);

Table B.2: Aggregation of GTAP sectors into final demand sectors. Note: Original 57 sectors from GTAP database were merged into 7 sectors according to final demand uses. This aggregation was used for the econometric analysis of CH_4 drivers.

Category	IPCC	GTAP	1997	2001	2004	2007	2011[a]
FAO CH_4 categories matched directly to a single GTAP sector:							
Rice Cultivation	n.a.	pdr	8.25	8.06	7.51	7.28	7.10
Burning Crops Residues	n.a.		0.32	0.30	0.29	0.28	0.28
of which:							
Maize		gro	0.14	0.13	0.13	0.13	0.13
Paddy Rice		pdr	0.08	0.08	0.07	0.07	0.07
Sugar Cane		c_b	0.01	0.01	0.01	0.01	0.01
Wheat		wht	0.09	0.08	0.08	0.07	0.07
Burning Savanna	n.a.	ctl	1.63	2.03	1.69	1.57	1.67
Enteric Fermentation	n.a.		31.36	30.78	30.10	29.50	27.85
of which:							
Cattle, dairy		rmk	5.93	5.70	5.53	5.39	5.24
Cattle, non-dairy[b]		ctl	25.08	24.73	24.24	23.78	22.29
Swines		oap	0.35	0.35	0.33	0.33	0.32
Manure Management	n.a.		3.15	3.07	2.95	2.89	2.74
of which:							
Cattle, dairy		rmk	0.75	0.70	0.66	0.63	0.59
Cattle, non-dairy[b]		ctl	1.08	1.04	1.00	0.98	0.92
Poultry/Swines[c]		oap	1.33	1.33	1.29	1.27	1.22
EDGAR CH_4 categories matched directly to a single GTAP sector:							
Coal Mining	1B1	coa	11.65	11.73	13.83	15.35	17.23
Other - Chemicals	2B	crp	0.04	0.04	0.05	0.05	0.06
Landfilling	6A	osg	9.57	9.23	9.01	8.89	8.53
Wastewater Treatment	6B	osg	9.39	9.90	9.77	9.50	9.22
EDGAR CH_4 categories matched to more than one GTAP sector:							
Combustion[d]	1A1 - 1A4		4.90	4.45	4.22	4.09	4.22
of which:							
Energy Industries	1A1	coa, oil, gas, p_c, ely, gdt	0.09	0.08	0.09	0.10	0.10
Industrial Sectors	1A2	omn, cmt, omt, vol, mil, pcr, sgr, ofd, b_t, tex, wap, lea, lum, ppp, crp, nmm, i_s, nfm, fmp, mvh, otn, ele, ome, omf, cns	0.14	0.37	0.35	0.35	0.34
Transport Sectors	1A3	otp, wtp, atp	0.27	0.01	0.01	0.01	0.01
Agriculture and Services	1A4	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, wtr, trd, cmn, ofi, isr, obs, osg	4.41	3.99	3.77	3.64	3.77
Oil and Gas Fugitives[e]	1B2	oil, gas, p_c, gdt, otp	19.73	20.37	20.54	20.56	21.09
Other - Metals[f]	2C	i_s, nfm	0.02	0.02	0.03	0.02	0.02

Table B.3: CH_4 Emissions from FAO and EDGAR categories (percentage of total annual emissions). Note: [a] EDGAR data for 2011 is extrapoleted. [b] Includes Asses, Buffalos, Camels, Goats, Horses, Llamas, Mules and Sheep. [c] Includes Chicken, Ducks and Turkeys and Swines. [d] Stationary and mobile combustion. [e] Including exploration, distribution, flaring, leakage at industrial plants, power stations, commercial and residential sectors, refining, storage, venting and transport. [f] Including Aluminium, ferroalloys, iron and steel production as well as other metals.

Variable	Description	Source
	Dependent variables	
ln CH_4 p.c., prod.	Log of production-based CH_4 emissions per capita. Raw CH_4 data was constructed from FAO and EDGAR data as well as the GTAP non-CO_2 emissions database.	own calc.
ln CH_4 p.c., fin. prod.	Log of final production-based CH_4 emissions per capita. Constructed by applying MRIOT constructed from GTAP data on production-based CH_4 emissions (see Appendix B).	own calc.
ln CH_4 p.c., cons.	Log of consumption-based CH_4 emissions per capita. Constructed by applying MRIOT constructed from GTAP data on production-based CH_4 emissions (see Appendix B).	own calc.
	Control variables	
Annex I	Dummy = 1 for members of Annex I of the Kyoto Protocol.[a]	UN
Food exports	Share of exports from food sectors (agriculture, livestock, food processing) relative to total exports.	GTAP
Fossil rents	Rents from fossil fuel production (including coal, gas and oil) as share of GDP.[a]	WDI
Fuel exports	Share of exports from fossil fuel sectors relative to total exports. Includes coal, gas and oil, mineral products and petrochemical products.	GTAP
HDI	Development categories ranging from 1 to 4 (highest to lowest) based on categories used in the Human Development Report (2016).[a]	HDI database/UN
ln(Income pc)	Log of real GDP (PPP) per capita.	WDI
Openness	Trade openness calculated as (X+M)/GDP.	GTAP
Polity IV	Index of democracy (10) vs. autocracy (–10)[a,b].	Polity IV
ln(Pop. density)	Log of number of inhabitants per square kilometer.	WDI
Urbanization %	Share of total population living in cities.	WDI
	Variables used for instrumentation	
ICC ratification	Dummy = 1 for Annex I members that ratified the Rome Statute of the International Criminal Court as instrument for Annex I ratification.	UN
ln(Income pc), lag 3	Lagged real GDP (PPP) per capita (3 lags) as instrument for real GDP (PPP) per capita.	WDI
Inv. growth, lag 3	Growth of total real investment (3 lags) as instrument for real GDP (PPP) per capita.	IMF/WDI

Table B.4: Definition of variables and data sources. Note: [a] Values for composite regions were obtained as GDP weighted averages. If GDP was not available from WDI data we sourced it from the UN Statistics Division. If data was missing for individual group members, group averages were used. [b] Data for HKG was missing in the Polity IV dataset. We imputed it by extapolating indicators of political freedom from Freedom House data and scaling this data to the scale used by Polity IV.

	N	Mean	Std. Dev.	Min.	Max.
		Dependent variables			
ln(CH_4 p.c. prod.)	390	0.062	0.677	-1.722	2.010
ln(CH_4 p.c. fin.prod.)	390	0.267	0.602	-1.332	1.674
ln(CH_4 p.c. cons.)	390	0.278	0.594	-1.319	1.675
		Control variables			
Annex I	390	0.279	0.449	0	1
Food exports	390	0.123	0.129	0.002	0.759
Fossil rents	390	0.042	0.082	0.000	0.476
Fuel exports	390	0.135	0.200	0.000	0.958
HDI middle	390	0.218	0.413	0	1
HDI high	390	0.236	0.425	0	1
HDI very high	390	0.408	0.492	0	1
ln(Income pc)	390	9.502	1.096	6.195	11.479
Openness	390	0.839	0.479	0.176	3.274
Polity IV	390	6.244	5.046	-7	10
ln(Pop. density)	390	-2.606	1.459	-6.030	2.002
Urbanization	390	0.629	0.216	0.118	1
		Instruments			
ICC ratification	390	0.305	0.461	0	1
ln(Income pc), lag 3	390	9.416	1.111	5.926	11.453
Inv. Growth, lag 3	390	0.108	1.551	-3.814	30.005

Table B.5: Descriptive statistics.

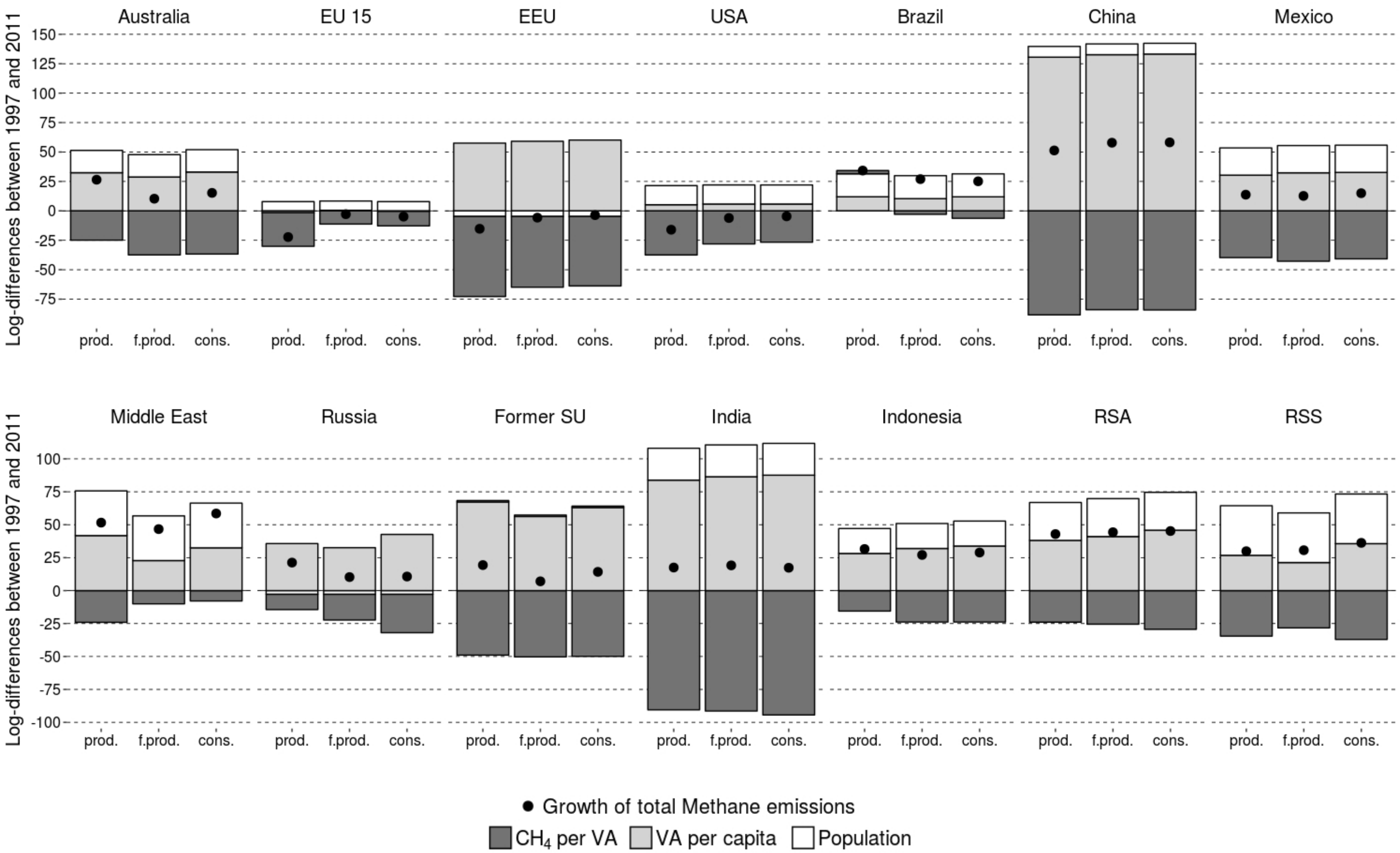

Figure B.1: Change in components of the Kaya-identity (1997 - 2011, selected regions). Note: The barplots show the log-differences of the components of the Kaya-identity between 1997 and 2011 for the 14 most important producers of CH_4 emissions. The Kaya identity decomposes total CH_4 emissions into CH_4 per value added, value added per capita, and population, according to the formula $CH_4 = \frac{CH_4}{VA} \cdot \frac{VA}{pop} \cdot pop$. The data is presented for the three inventories in our dataset: standard production, final production and consumption. Additionally we show the growth rate of total emissions per country (in log-differences), marked as black dot.

C Detailed results

C.1 First-stage results of IV estimates

Table C.1 reports the results of the first-stage regressions of the IV and the FE-IV estimates corresponding to Table 4. The first stage results confirm the relevance of the instruments; ICC ratification has a positive and highly statistically significant effect on the ratification of Annex I of the Kyoto protocol, and lagged income and investment growth have a positive and statistically significant effect on income. Furthermore, the Hansen-J test reported in Table 4 for each specification gives further evidence on the validity (exogeneity) of the instruments used.

C.2 Economy-wide results

Table C.2 reports additional results for economy-wide OLS regressions including all regressors and the squared income term. For CH_4 production inventories both the OLS and the IV regressions result in a significantly positive income coefficient and a significantly negative squared income term, indicating an inverse-U relationship between income and CH_4 production; yet, the implied turning points lie out of sample, indicating that the inverse-U relationship is an artifact from the estimation and we cannot reject a linear relationship; thus we skip the squared term from the estimation in the main analysis. For CH_4 embodied in final production both income terms turn out to be statistically insignificant in the polynomial specification. For CH_4 consumption inventories the coefficient of the income term is insignificant, while its square is significantly positive in the OLS and IV regressions; because of the insignificant level term, we also skip the square from the estimations in the main analysis.

Table C.3 reports additional results for economy-wide FE regressions including all regressors and the squared income term. When controlling for individual-FE both income terms turn statistically insignificant throughout. Thus, in the main analysis we omit the squared income term and all other insignificant covariates from the model specification.

	OLS all inventories		FE prod. and cons.		FE fin.prod.	
	Annex I	ln(Income)	Annex I	ln(Income)	Annex I	ln(Income)
ICC	0.621***	-0.020*	0.586***	-0.029*	0.524***	-0.025
	(0.056)	(0.011)	(0.057)	(0.015)	(0.065)	(0.016)
ln(Income), lag 3	0.004	0.923***	0.141	0.790***	0.154	0.789***
	(0.030)	(0.011)	(0.116)	(0.041)	(0.114)	(0.038)
Investment growth, lag 3	-0.000	0.003*	0.007***	0.003**	0.006***	0.003**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Openness	0.043	0.020**	0.006	-0.036	0.003	-0.036
	(0.028)	(0.008)	(0.106)	(0.022)	(0.111)	(0.024)
Food exports	-0.160	-0.117***				
	(0.102)	(0.041)				
Fuel exports	-0.179**	-0.014			-0.572***	0.027
	(0.078)	(0.028)			(0.173)	(0.053)
Urbanization	-0.051	-0.009			-2.398**	0.158
	(0.097)	(0.030)			(1.014)	(0.304)
ln(Pop. density)	-0.015	0.000				
	(0.011)	(0.003)				
Polity IV	0.005*	-0.000				
	(0.003)	(0.001)				
Fossil rents	0.312	-0.037				
	(0.227)	(0.089)				
HDI middle	-0.030	0.107***				
	(0.045)	(0.020)				
HDI high	0.027	0.178***				
	(0.066)	(0.024)				
HDI very high	0.062	0.209***				
	(0.101)	(0.030)				
2001	-0.125***	-0.023**	-0.113**	0.005	-0.086*	0.003
	(0.045)	(0.011)	(0.048)	(0.011)	(0.046)	(0.012)
2004	0.151***	0.002	0.160***	0.046***	0.244***	0.041***
	(0.037)	(0.013)	(0.050)	(0.012)	(0.059)	(0.015)
2007	0.162***	0.041***	0.165***	0.107***	0.279***	0.101***
	(0.032)	(0.012)	(0.053)	(0.014)	(0.066)	(0.018)
2011	0.181***	-0.050***	0.161***	0.045***	0.311***	0.036
	(0.035)	(0.012)	(0.061)	(0.016)	(0.078)	(0.023)
Constant	-0.089	0.679***				
	(0.214)	(0.084)				
R^2	0.700	0.996	0.585	0.882	0.606	0.882
N	390	390	390	390	390	390

Table C.1: First stage results of IV regressions. Note: First-stage estimates of the IV and FE-IV specifications of Table 4.

	prod.	(1) OLS fin.prod.	cons.	prod.	(2) IV fin.prod.	cons.
ln(Income)	0.989**	0.203	-0.284	0.914**	0.139	-0.340
	(0.396)	(0.308)	(0.280)	(0.392)	(0.297)	(0.272)
ln(Income), squared	-0.037*	0.007	0.033**	-0.036*	0.008	0.034**
	(0.021)	(0.016)	(0.015)	(0.021)	(0.016)	(0.014)
Annex I	-0.005	0.035	0.059	0.099	0.054	0.076
	(0.065)	(0.045)	(0.040)	(0.118)	(0.075)	(0.066)
Openness	0.136**	0.194***	0.126***	0.133**	0.193***	0.125***
	(0.056)	(0.041)	(0.037)	(0.057)	(0.042)	(0.038)
ln(Pop. density)	-0.298***	-0.137***	-0.102***	-0.292***	-0.136***	-0.101***
	(0.019)	(0.015)	(0.015)	(0.019)	(0.015)	(0.015)
Food exports (% of total exports)	1.224***	0.690***	0.224	1.234***	0.674***	0.219
	(0.268)	(0.195)	(0.153)	(0.267)	(0.196)	(0.154)
Fuel exports (% of total exports)	-0.293	-0.075	0.049	-0.251	-0.064	0.067
	(0.223)	(0.231)	(0.198)	(0.223)	(0.230)	(0.198)
Urbanization	-0.072	0.669***	0.770***	0.028	0.710***	0.789***
	(0.217)	(0.165)	(0.154)	(0.227)	(0.170)	(0.155)
Polity IV	0.010	0.004	0.004	0.011*	0.004	0.004
	(0.007)	(0.006)	(0.005)	(0.006)	(0.006)	(0.005)
Fossil rents	1.345**	-0.459	-0.668	1.368**	-0.472	-0.677
	(0.567)	(0.551)	(0.486)	(0.555)	(0.551)	(0.486)
HDI middle	0.029	-0.040	-0.029	0.087	0.000	0.001
	(0.134)	(0.110)	(0.102)	(0.133)	(0.109)	(0.101)
HDI high	0.070	-0.037	0.000	0.132	0.020	0.041
	(0.161)	(0.135)	(0.124)	(0.159)	(0.133)	(0.123)
HDI very high	-0.016	-0.008	-0.001	0.056	0.067	0.052
	(0.187)	(0.159)	(0.144)	(0.188)	(0.159)	(0.144)
2001	-0.030	-0.017	-0.019	-0.024	-0.017	-0.019
	(0.069)	(0.054)	(0.050)	(0.069)	(0.054)	(0.050)
2004	-0.049	-0.029	-0.040	-0.083	-0.035	-0.045
	(0.071)	(0.056)	(0.050)	(0.081)	(0.061)	(0.055)
2007	-0.067	-0.081	-0.097*	-0.100	-0.088	-0.102*
	(0.072)	(0.056)	(0.049)	(0.077)	(0.061)	(0.055)
2011	-0.079	-0.115*	-0.133**	-0.115	-0.122*	-0.137**
	(0.073)	(0.059)	(0.051)	(0.079)	(0.064)	(0.056)
Constant	-6.964***	-3.244**	-0.850	-6.464***	-2.858**	-0.529
	(1.815)	(1.410)	(1.271)	(1.792)	(1.355)	(1.235)
Hansen-J (p)	-	-	-	0.467	0.253	0.213
Turning point, log-level	13.241	-	-	12.566	-	-
Turning point, level	563 149	-	-	286 540	-	-
R^2	0.641	0.752	0.786	0.639	0.751	0.786
N	390	390	390	390	390	390

Table C.2: Economy-wide OLS results with squared income term.

		(1) FE			(2) IV-FE	
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	-0.276	0.066	-0.081	-0.249	0.258	0.007
	(0.699)	(0.609)	(0.831)	(0.590)	(0.746)	(1.015)
ln(Income), squared	0.036	0.011	0.022	0.036	-0.001	0.017
	(0.042)	(0.036)	(0.049)	(0.036)	(0.045)	(0.061)
Annex I	-0.044*	0.051*	0.075*	-0.089	0.066	0.090
	(0.023)	(0.027)	(0.041)	(0.090)	(0.084)	(0.098)
Openness	0.085	0.064	0.013	0.089	0.066	0.014
	(0.063)	(0.083)	(0.108)	(0.066)	(0.082)	(0.106)
ln(Pop. density)	-0.041	-0.179	-0.083	-0.092	-0.149	-0.045
	(0.154)	(0.202)	(0.261)	(0.199)	(0.218)	(0.284)
Food exports	0.000	-0.055	-0.155	-0.006	-0.019	-0.130
	(0.197)	(0.173)	(0.252)	(0.187)	(0.176)	(0.271)
Fuel exports	0.040	-0.227*	-0.004	0.015	-0.226*	-0.001
	(0.085)	(0.126)	(0.189)	(0.094)	(0.132)	(0.195)
Urbanization	0.688	0.946*	1.003	0.572	0.973	1.026
	(0.504)	(0.566)	(0.633)	(0.535)	(0.625)	(0.695)
Polity IV	0.005*	0.004	0.004	0.003	0.001	0.001
	(0.003)	(0.004)	(0.005)	(0.002)	(0.002)	(0.003)
Fossil rents	0.358	0.106	0.159	0.245	0.133	0.194
	(0.299)	(0.330)	(0.407)	(0.327)	(0.353)	(0.421)
HDI middle	-0.002	0.007	0.040	-0.017	0.009	0.045
	(0.055)	(0.061)	(0.079)	(0.053)	(0.063)	(0.081)
HDI high	0.039	0.073	0.142*	0.013	0.079	0.148*
	(0.062)	(0.067)	(0.085)	(0.062)	(0.070)	(0.089)
HDI very high	0.043	0.080	0.168*	0.004	0.082	0.167
	(0.073)	(0.082)	(0.097)	(0.071)	(0.086)	(0.102)
2001	-0.060***	-0.030	-0.037	-0.054***	-0.031	-0.041
	(0.015)	(0.019)	(0.026)	(0.018)	(0.025)	(0.032)
2004	-0.108***	-0.053	-0.083*	-0.082	-0.061	-0.094
	(0.037)	(0.034)	(0.048)	(0.061)	(0.060)	(0.076)
2007	-0.175***	-0.105**	-0.155**	-0.147*	-0.110	-0.166
	(0.056)	(0.051)	(0.070)	(0.079)	(0.079)	(0.103)
2011	-0.198***	-0.121*	-0.186**	-0.167*	-0.127	-0.198*
	(0.069)	(0.061)	(0.081)	(0.096)	(0.091)	(0.119)
Hansen-J (p)	-	-	-	0.222	0.240	0.254
R^2	0.217	0.203	0.183	-	-	-
R^2 within	-	-	-	0.204	0.197	0.179
N	390	390	390	390	390	390

Table C.3: Economy-wide FE results including squared income term. Note: R^2 within refers to within country.

C.3 Sectoral FE results

Tables C.4 to C.6 summarize the linear and polynomial sectoral results for CH_4 production, final production, and consumption inventories, respectively. They correspond to the threshold tables 6 to 8 in the main text of the paper. The results are largely similar to the results of the threshold models reported in the main text. The inverse-U relationship between income and CH_4 embodied in final production of and consumption from the manufacturing sector is driven by few observations with extreme values (identified as outliers via box plots). When dropping these observations (Mozambique in 1997 and 2001 for CH_4 consumption, and additionally Uganda in 1997 for final production) both income terms turn statistically insignificant for the final production inventory, and for the consumption inventory the squared income term turns insignificant.

	IV-FE prod. (linear and polynomial specifications)						
	agr	liv	egy	mfc	ser	trn	wab
ln(Income)	0.343*	0.005	0.877***	0.719***	-0.543	14.984**	0.471**
	(0.203)	(0.149)	(0.330)	(0.174)	(0.662)	(7.576)	(0.189)
ln(Income), squared						-0.773*	
						(0.427)	
Annex I	0.088	0.365	-0.367**	0.042	0.644**	-0.527	-0.179**
	(0.146)	(0.283)	(0.145)	(0.150)	(0.301)	(0.489)	(0.074)
Openness	0.197***	0.631*	0.267	0.199*	-0.499	0.297	0.012
	(0.075)	(0.376)	(0.164)	(0.114)	(0.325)	(0.311)	(0.053)
Food exports				1.403**			
				(0.640)			
Fossil rents				-2.272*			
				(1.164)			
Polity IV				-0.018*			
				(0.010)			
HDI medium					0.893**		
					(0.451)		
HDI high					1.466***		
					(0.565)		
HDI very high					1.608**		
					(0.640)		
Hansen-J (p)	0.257	0.983	0.138	0.286	0.681	0.334	0.274
Turning point (ln)	-	-	-	-	-	9.695	-
Turning point	-	-	-	-	-	16 241	-
R^2 within	0.052	0.015	0.128	0.374	0.034	0.214	0.112
N	390	390	390	390	390	390	390

Table C.4: Linear and polynomial sectoral results for CH_4 production. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2). R^2 within stands for R^2 within country.

	IV-FE final production (linear and polynomial specifications)						
	agr	liv	egy	mfc	serv	trn	wab
ln(Income)	0.342	0.015	0.286	4.563**	0.115	1.109***	0.415***
	(0.251)	(0.172)	(0.361)	(2.099)	(0.341)	(0.385)	(0.097)
ln(Income), squared				-0.206*			
				(0.118)			
Annex I	0.589***	-0.174	-0.305*	-0.004	0.267**	0.491**	-0.126
	(0.164)	(0.154)	(0.170)	(0.155)	(0.128)	(0.203)	(0.077)
Openness	-0.280*	0.106	-0.001	0.347***	-0.049	0.087	0.128
	(0.162)	(0.092)	(0.211)	(0.078)	(0.149)	(0.197)	(0.098)
Food exports							1.165***
							(0.279)
Fuel exports		0.665**	-1.383**		-0.707*	-1.902**	
		(0.267)	(0.580)		(0.377)	(0.780)	
HDI medium	0.192				0.224**		
	(0.121)				(0.100)		
HDI high	0.318*				0.388***		
	(0.193)				(0.146)		
HDI very high	0.255				0.288		
	(0.243)				(0.193)		
Hansen-J (p)	0.553	0.233	0.267	0.404	0.280	0.115	0.287
Turning point	-	-	-	11.065	-	-	-
Turning point (PPP)	-	-	-	63 876	-	-	-
R^2 within	0.157	0.164	0.165	0.162	0.282	0.319	0.114
N	390	390	390	390	390	390	390

Table C.5: Linear and polynomial sectoral results for CH_4 final production. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2). R^2 within stands for R^2 within country.

Tables C.7 to C.13 report the sectoral FE and IV-FE results for the full set of covariates with and without the squared income term. In most sectors the squared income term is statistically insignificant. Exceptions apply (for some specifications) to CH_4 production in the energy, service, and transport sectors, and for final production and consumption in the manufacturing sector. For the energy and service sectors the statistical significance of the squared income term vanishes when accounting for the the potential endogeneity of income. The same is true for CH_4 embodied in final production in the manufacturing sector. For consumption inventories in the manufacturing sector the inverse-U relationship is driven by two outlying observations (Mozambique in 1997 and 2001), whose deletion leads to insignificant income terms. For these sectors we omit the squared terms from the main analysis. The two statistically significant income terms for production inventories in the transport sector imply an inverse-U shaped relationship between income and CH_4 production.

	IV-FE cons. (linear and polynomial specifications)						
	agr	liv	egy	mfc	serv	trn	wab
ln(Income)	0.452**	0.065	0.244	4.955***	0.136	1.411***	0.392***
	(0.187)	(0.206)	(0.478)	(1.587)	(0.349)	(0.414)	(0.103)
ln(Income), squared				-0.227**			
				(0.090)			
Annex I	0.664***	-0.307*	-0.046	0.087	0.285**	0.574***	-0.182**
	(0.135)	(0.160)	(0.227)	(0.118)	(0.123)	(0.179)	(0.089)
Openness	0.006	0.017	-0.074	0.065	-0.055	-0.048	0.122
	(0.120)	(0.121)	(0.247)	(0.103)	(0.169)	(0.202)	(0.093)
Food exports							1.279***
							(0.317)
Fuel exports		0.503*	-2.214***				
		(0.270)	(0.851)				
ln(Population density)			1.322*				
			(0.791)				
Polity IV							0.007*
							(0.004)
HDI medium	0.168		0.341		0.265***		
	(0.129)		(0.230)		(0.102)		
HDI high	0.369*		0.565*		0.433***		
	(0.193)		(0.296)		(0.149)		
HDI very high	0.303		0.613*		0.375**		
	(0.226)		(0.329)		(0.190)		
Hansen-J (p)	0.320	0.139	0.233	0.314	0.290	0.090	0.206
Turning point (ln)	-	-	-	10.907	-	-	-
Turning point	-	-	-	54 560	-	-	-
R^2 within	0.181	0.080	0.249	0.263	0.254	0.306	0.092
N	390	390	390	390	390	390	390

Table C.6: Linear and polynomial sectoral results for CH_4 consumption. Note: IV-FE results (specifications include only statistically significant and baseline regressors). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table B.2). R^2 within stands for R^2 within country.

		(1) FE			(2) IV-FE			(3) FE			(4) IV-FE	
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	-1.400	-0.075	-0.064	-0.377	0.912	1.173	0.113	0.197	0.387	0.377*	0.361	0.500**
	(1.474)	(1.898)	(1.831)	(1.862)	(1.985)	(1.922)	(0.132)	(0.261)	(0.236)	(0.199)	(0.242)	(0.201)
ln(Income), squared	0.088	0.016	0.026	0.043	-0.032	-0.039						
	(0.086)	(0.106)	(0.102)	(0.115)	(0.118)	(0.115)						
Annex I	0.032	0.377***	0.385***	0.033	0.646***	0.757***	0.046	0.379***	0.390***	0.045	0.628***	0.735***
	(0.096)	(0.090)	(0.084)	(0.342)	(0.232)	(0.218)	(0.099)	(0.092)	(0.082)	(0.310)	(0.218)	(0.196)
Openness	0.271**	-0.214	0.039	0.282**	-0.231	0.054	0.259**	-0.216	0.036	0.277**	-0.224	0.058
	(0.116)	(0.198)	(0.137)	(0.125)	(0.224)	(0.139)	(0.109)	(0.190)	(0.138)	(0.120)	(0.218)	(0.144)
ln(Pop. density)	0.144	0.664	0.455	0.083	0.930	0.924	0.028	0.643	0.420	0.028	0.957	0.963*
	(0.567)	(0.590)	(0.586)	(0.754)	(0.617)	(0.605)	(0.546)	(0.518)	(0.509)	(0.784)	(0.596)	(0.584)
2001	-0.184**	-0.159**	-0.193***	-0.181*	-0.194**	-0.240***	-0.159**	-0.154**	-0.186***	-0.170*	-0.201***	-0.249***
	(0.083)	(0.074)	(0.062)	(0.095)	(0.082)	(0.074)	(0.073)	(0.062)	(0.054)	(0.095)	(0.075)	(0.069)
2004	-0.216	-0.277**	-0.335***	-0.227	-0.446***	-0.568***	-0.173	-0.269***	-0.323***	-0.210	-0.454***	-0.577***
	(0.139)	(0.114)	(0.098)	(0.249)	(0.161)	(0.152)	(0.116)	(0.100)	(0.091)	(0.258)	(0.160)	(0.155)
2007	-0.296	-0.398**	-0.470***	-0.325	-0.591***	-0.726***	-0.228	-0.386***	-0.449***	-0.296	-0.608***	-0.746***
	(0.185)	(0.165)	(0.141)	(0.290)	(0.207)	(0.187)	(0.146)	(0.137)	(0.122)	(0.304)	(0.197)	(0.184)
2011	-0.204	-0.442**	-0.549***	-0.250	-0.665***	-0.852***	-0.130	-0.429**	-0.527***	-0.218	-0.682***	-0.873***
	(0.198)	(0.206)	(0.166)	(0.332)	(0.248)	(0.215)	(0.158)	(0.175)	(0.145)	(0.350)	(0.236)	(0.213)
Food exports	0.814	0.281	0.002	1.001	0.436	0.312	0.966	0.308	0.047	1.083	0.381	0.242
	(0.592)	(0.702)	(0.661)	(0.774)	(0.640)	(0.553)	(0.641)	(0.713)	(0.651)	(0.748)	(0.652)	(0.553)
Fuel exports	0.323	-0.349	-0.370	0.389	-0.137	-0.128	0.296	-0.354	-0.378	0.389	-0.131	-0.126
	(0.630)	(0.398)	(0.352)	(0.693)	(0.376)	(0.308)	(0.630)	(0.403)	(0.359)	(0.698)	(0.374)	(0.306)
Urbanization	0.027	0.662	0.056	-0.149	1.047	0.717	-0.277	0.608	-0.035	-0.285	1.130	0.799
	(1.315)	(1.168)	(0.999)	(1.421)	(1.406)	(1.369)	(1.212)	(1.175)	(1.048)	(1.521)	(1.383)	(1.401)
Polity IV	0.001	-0.007	-0.002	0.001	-0.001	0.002	0.001	-0.007	-0.002	0.001	-0.001	0.002
	(0.008)	(0.009)	(0.010)	(0.009)	(0.009)	(0.011)	(0.008)	(0.010)	(0.010)	(0.009)	(0.010)	(0.011)
Fossil rents	-0.638	-2.861**	-2.286*	-0.341	-2.024	-1.405	-0.790	-2.888**	-2.331*	-0.405	-2.018	-1.385
	(1.402)	(1.301)	(1.244)	(1.591)	(1.313)	(1.297)	(1.494)	(1.384)	(1.304)	(1.664)	(1.357)	(1.290)
HDI middle	0.031	0.128	0.079	-0.059	0.135	0.111	-0.014	0.120	0.066	-0.083	0.147	0.127
	(0.132)	(0.113)	(0.120)	(0.130)	(0.118)	(0.135)	(0.119)	(0.101)	(0.104)	(0.142)	(0.123)	(0.134)
HDI high	0.076	0.292	0.286	-0.050	0.309	0.359*	0.032	0.284*	0.273	-0.074	0.318	0.371*
	(0.176)	(0.184)	(0.181)	(0.200)	(0.192)	(0.200)	(0.160)	(0.169)	(0.167)	(0.214)	(0.195)	(0.201)
HDI very high	0.058	0.269	0.264	-0.065	0.278	0.320	0.030	0.264	0.256	-0.081	0.282	0.326
	(0.226)	(0.218)	(0.217)	(0.253)	(0.236)	(0.236)	(0.217)	(0.211)	(0.207)	(0.260)	(0.238)	(0.236)
Hansen-J (p)	-	-	-	0.234	0.339	0.262	-	-	-	0.244	0.333	0.258
R^2	0.072	0.244	0.276	-	-	-	0.068	0.244	0.276	-	-	-
R^2 within	-	-	-	0.065	0.202	0.188	-	-	-	0.061	0.207	0.198
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.7: FE and IV-FE results for the agriculture sector. Note: R^2 within stands for R^2 within country.

	(1) FE			(2) IV-FE			(3) FE			(4) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	-6.341	-0.599	-0.871	-3.213	0.588	-0.816	0.456	0.110	0.096	0.119	-0.083	-0.002
	(5.759)	(1.584)	(1.502)	(3.096)	(1.397)	(1.719)	(0.363)	(0.163)	(0.186)	(0.226)	(0.161)	(0.199)
ln(Income), squared	0.394	0.041	0.056	0.194	-0.039	0.048						
	(0.353)	(0.094)	(0.088)	(0.185)	(0.081)	(0.103)						
Annex I	0.082	-0.058	-0.077	0.612	-0.081	-0.183	0.146	-0.052	-0.068	0.748	-0.105	-0.164
	(0.100)	(0.063)	(0.082)	(0.659)	(0.247)	(0.262)	(0.155)	(0.069)	(0.089)	(0.754)	(0.245)	(0.273)
Openness	0.716	0.069	0.008	0.664	0.034	0.020	0.665	0.064	0.001	0.658	0.033	0.010
	(0.529)	(0.114)	(0.134)	(0.472)	(0.129)	(0.157)	(0.555)	(0.112)	(0.137)	(0.485)	(0.119)	(0.154)
ln(Pop. density)	1.202	-0.295	-0.150	1.554	-0.483	-0.267	0.680	-0.350	-0.224	1.486	-0.472	-0.322
	(0.990)	(0.320)	(0.397)	(1.468)	(0.448)	(0.536)	(0.636)	(0.254)	(0.332)	(1.399)	(0.419)	(0.507)
2001	-0.178***	-0.086*	-0.090*	-0.175**	-0.048	-0.068	-0.067	-0.074*	-0.074*	-0.132**	-0.057	-0.057
	(0.055)	(0.045)	(0.053)	(0.076)	(0.054)	(0.070)	(0.059)	(0.043)	(0.044)	(0.056)	(0.051)	(0.061)
2004	-0.419*	-0.237***	-0.203**	-0.596	-0.150	-0.114	-0.228***	-0.218***	-0.176**	-0.565	-0.155	-0.098
	(0.233)	(0.086)	(0.100)	(0.450)	(0.155)	(0.183)	(0.083)	(0.063)	(0.081)	(0.424)	(0.147)	(0.175)
2007	-0.658	-0.295**	-0.300**	-0.788	-0.159	-0.185	-0.351**	-0.263***	-0.256**	-0.711	-0.171	-0.155
	(0.408)	(0.125)	(0.137)	(0.595)	(0.193)	(0.233)	(0.155)	(0.081)	(0.104)	(0.530)	(0.176)	(0.212)
2011	-0.821	-0.315**	-0.330**	-0.979	-0.159	-0.196	-0.489**	-0.280***	-0.283**	-0.905	-0.171	-0.165
	(0.505)	(0.150)	(0.158)	(0.729)	(0.234)	(0.267)	(0.239)	(0.103)	(0.127)	(0.667)	(0.216)	(0.248)
Food exports	-0.582	-1.030**	-0.951*	-0.124	-0.959**	-1.031**	0.101	-0.959**	-0.854*	0.263	-1.036**	-0.935**
	(0.692)	(0.488)	(0.487)	(0.510)	(0.454)	(0.479)	(0.461)	(0.445)	(0.442)	(0.533)	(0.426)	(0.420)
Fuel exports	0.406	0.497**	0.553**	0.608	0.411*	0.433*	0.286	0.484**	0.536**	0.599	0.411*	0.429*
	(0.362)	(0.196)	(0.214)	(0.561)	(0.228)	(0.254)	(0.269)	(0.186)	(0.211)	(0.556)	(0.230)	(0.254)
Urbanization	3.618	0.748	1.084	4.207	0.604	0.910	2.255	0.606	0.890	3.834	0.663	0.784
	(2.701)	(1.209)	(0.951)	(3.480)	(1.393)	(1.164)	(1.630)	(1.035)	(0.845)	(3.213)	(1.315)	(1.116)
Polity IV	0.001	0.000	-0.002	0.005	-0.004	-0.008	-0.002	-0.000	-0.002	0.005	-0.004	-0.008
	(0.005)	(0.005)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.007)	(0.005)	(0.006)
Fossil rents	-0.527	1.164	1.293	0.410	1.068	0.996	-1.210	1.093	1.196	0.219	1.054	0.953
	(0.897)	(0.862)	(0.806)	(0.883)	(0.844)	(0.833)	(1.283)	(0.852)	(0.798)	(0.705)	(0.830)	(0.821)
HDI middle	-0.030	0.058	0.076	0.056	0.067	0.068	-0.233	0.036	0.047	-0.023	0.089	0.052
	(0.084)	(0.124)	(0.128)	(0.133)	(0.123)	(0.122)	(0.223)	(0.135)	(0.141)	(0.119)	(0.121)	(0.128)
HDI high	-0.090	0.094	0.128	0.115	0.101	0.098	-0.283	0.074	0.101	0.058	0.122	0.085
	(0.133)	(0.149)	(0.150)	(0.200)	(0.144)	(0.140)	(0.277)	(0.164)	(0.166)	(0.176)	(0.143)	(0.144)
HDI very high	-0.226	0.056	0.190	0.003	0.087	0.173	-0.352	0.043	0.172	-0.024	0.101	0.169
	(0.222)	(0.170)	(0.179)	(0.182)	(0.153)	(0.156)	(0.320)	(0.181)	(0.192)	(0.184)	(0.152)	(0.162)
Hansen-J (p)	-	-	-	0.403	0.177	0.314	-	-	-	0.448	0.191	0.291
R^2	0.117	0.209	0.170	-	-	-	0.068	0.207	0.167	-	-	-
R^2 within	-	-	-	0.038	0.195	0.158	-	-	-	-0.027	0.199	0.156
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.8: FE and IV-FE results for the livestock sector. Note: R^2 within stands for R^2 within country.

	(1) FE prod.	(1) FE fin.prod.	(1) FE cons.	(2) IV-FE prod.	(2) IV-FE fin.prod.	(2) IV-FE cons.	(3) FE prod.	(3) FE fin.prod.	(3) FE cons.	(4) IV-FE prod.	(4) IV-FE fin.prod.	(4) IV-FE cons.
ln(Income)	3.716**	0.734	0.395	2.947	-0.266	-1.099	0.707***	0.318	0.401*	0.930***	0.344	0.343
	(1.445)	(2.260)	(2.632)	(2.038)	(2.865)	(3.285)	(0.208)	(0.237)	(0.240)	(0.333)	(0.339)	(0.377)
ln(Income), squared	-0.175*	-0.024	0.000	-0.119	0.035	0.084						
	(0.088)	(0.128)	(0.149)	(0.129)	(0.169)	(0.187)						
Annex I	-0.127	-0.102	-0.042	-0.417	-0.221	-0.077	-0.155	-0.106	-0.042	-0.470	-0.202	-0.032
	(0.131)	(0.100)	(0.097)	(0.277)	(0.204)	(0.232)	(0.140)	(0.105)	(0.103)	(0.293)	(0.212)	(0.243)
Openness	0.279	0.088	0.042	0.301*	0.122	0.085	0.301*	0.091	0.042	0.322*	0.117	0.073
	(0.170)	(0.212)	(0.205)	(0.179)	(0.213)	(0.196)	(0.153)	(0.211)	(0.206)	(0.172)	(0.216)	(0.203)
ln(Pop. density)	-0.388	1.177	1.712**	-0.878	1.173	1.868***	-0.157	1.209*	1.712***	-0.761	1.148*	1.802***
	(0.705)	(0.721)	(0.710)	(0.833)	(0.746)	(0.708)	(0.661)	(0.631)	(0.604)	(0.801)	(0.683)	(0.626)
2001	0.010	0.181**	0.133*	0.047	0.156*	0.087	-0.039	0.174***	0.133**	0.015	0.164**	0.106*
	(0.113)	(0.072)	(0.079)	(0.138)	(0.083)	(0.085)	(0.097)	(0.061)	(0.064)	(0.123)	(0.065)	(0.064)
2004	0.100	0.313**	0.238	0.272	0.333*	0.195	0.016	0.301**	0.239*	0.232	0.341*	0.216
	(0.221)	(0.148)	(0.156)	(0.302)	(0.202)	(0.217)	(0.195)	(0.123)	(0.122)	(0.291)	(0.183)	(0.196)
2007	0.111	0.239	0.171	0.277	0.244	0.103	-0.025	0.220	0.171	0.200	0.261	0.146
	(0.293)	(0.206)	(0.225)	(0.394)	(0.281)	(0.302)	(0.248)	(0.160)	(0.167)	(0.364)	(0.237)	(0.259)
2011	0.067	0.164	0.032	0.247	0.179	-0.034	-0.080	0.144	0.032	0.165	0.197	0.011
	(0.312)	(0.232)	(0.247)	(0.427)	(0.314)	(0.334)	(0.263)	(0.178)	(0.175)	(0.395)	(0.267)	(0.287)
Food exports	1.442	1.519	2.027	1.557	1.367	1.845	1.140	1.477	2.027	1.315	1.435	2.018
	(1.066)	(1.074)	(1.531)	(0.991)	(1.091)	(1.513)	(0.984)	(1.095)	(1.626)	(0.880)	(1.059)	(1.605)
Fuel exports	-0.003	-0.886**	-1.661*	-0.001	-0.945**	-1.668*	0.050	-0.878**	-1.661*	0.011	-0.949**	-1.674*
	(0.241)	(0.422)	(0.938)	(0.224)	(0.446)	(0.968)	(0.262)	(0.416)	(0.927)	(0.234)	(0.447)	(0.965)
Urbanization	1.226	-1.219	0.107	0.994	-1.167	0.489	1.829	-1.136	0.106	1.301	-1.256	0.286
	(1.640)	(1.603)	(1.582)	(1.631)	(1.691)	(1.748)	(1.644)	(1.557)	(1.448)	(1.604)	(1.602)	(1.592)
Polity IV	-0.001	-0.007	-0.001	-0.003	-0.027	-0.023	0.001	-0.006	-0.001	-0.002	-0.027	-0.023
	(0.010)	(0.023)	(0.024)	(0.010)	(0.017)	(0.018)	(0.010)	(0.023)	(0.024)	(0.010)	(0.017)	(0.017)
Fossil rents	0.575	-1.090	-0.506	-0.308	-1.138	-0.328	0.877	-1.048	-0.507	-0.207	-1.170	-0.396
	(1.038)	(1.590)	(1.631)	(1.244)	(1.700)	(1.695)	(0.997)	(1.625)	(1.663)	(1.240)	(1.716)	(1.707)
HDI middle	-0.048	0.311	0.317	-0.141	0.310	0.365	0.043	0.323	0.317	-0.098	0.295	0.331
	(0.175)	(0.234)	(0.228)	(0.184)	(0.241)	(0.248)	(0.178)	(0.224)	(0.203)	(0.191)	(0.235)	(0.221)
HDI high	0.075	0.459	0.517*	-0.090	0.432	0.562*	0.160	0.471*	0.517**	-0.056	0.421	0.536*
	(0.203)	(0.277)	(0.274)	(0.220)	(0.280)	(0.298)	(0.199)	(0.261)	(0.248)	(0.226)	(0.272)	(0.277)
HDI very high	0.029	0.521*	0.614*	-0.186	0.454	0.630*	0.085	0.528*	0.614**	-0.175	0.448	0.618*
	(0.228)	(0.308)	(0.313)	(0.240)	(0.308)	(0.330)	(0.228)	(0.297)	(0.294)	(0.250)	(0.304)	(0.320)
Hansen-J (p)	-	-	-	0.114	0.194	0.169	-	-	-	0.105	0.195	0.171
Turning point (log)	10.645	-	-	-	-	-	-	-	-	-	-	-
Turning point	41 971	-	-	-	-	-	-	-	-	-	-	-
R^2	0.207	0.223	0.273	-	-	-	0.188	0.223	0.273	-	-	-
R^2 within	-	-	-	0.160	0.206	0.260	-	-	-	0.133	0.209	0.263
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.9: FE and IV-FE results for the energy sector. Note: R^2 within stands for R^2 within country.

	(1) FE			(2) IV-FE			(3) FE			(4) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	1.738	4.652**	3.912**	2.803	4.058	4.752***	0.634***	0.731***	0.963***	0.533***	0.913***	0.954***
	(1.419)	(2.142)	(1.758)	(1.797)	(2.485)	(1.841)	(0.183)	(0.215)	(0.180)	(0.207)	(0.299)	(0.258)
ln(Income), squared	-0.064	-0.227*	-0.171*	-0.132	-0.181	-0.220**						
	(0.081)	(0.116)	(0.097)	(0.108)	(0.136)	(0.101)						
Annex I	-0.096	0.048	0.043	0.089	-0.040	0.118	-0.107	0.011	0.015	0.020	-0.138	-0.002
	(0.147)	(0.064)	(0.069)	(0.214)	(0.229)	(0.154)	(0.146)	(0.071)	(0.073)	(0.212)	(0.212)	(0.147)
Openness	0.157	0.234**	0.074	0.151	0.252**	0.074	0.165	0.264*	0.096	0.166	0.260*	0.080
	(0.100)	(0.108)	(0.119)	(0.104)	(0.110)	(0.114)	(0.107)	(0.144)	(0.146)	(0.113)	(0.144)	(0.147)
ln(Pop. density)	-0.478	-0.092	0.139	-0.336	-0.145	0.190	-0.393	0.209	0.365	-0.226	-0.051	0.315
	(0.473)	(0.426)	(0.429)	(0.539)	(0.619)	(0.479)	(0.476)	(0.583)	(0.533)	(0.521)	(0.737)	(0.567)
2001	0.457***	-0.044	-0.072*	0.455***	-0.054	-0.070	0.439***	-0.108	-0.120**	0.426***	-0.089	-0.114**
	(0.091)	(0.046)	(0.040)	(0.103)	(0.065)	(0.048)	(0.086)	(0.066)	(0.046)	(0.102)	(0.084)	(0.054)
2004	0.614***	-0.047	-0.013	0.545***	-0.051	-0.033	0.583***	-0.156*	-0.096	0.513***	-0.087	-0.078
	(0.132)	(0.097)	(0.090)	(0.194)	(0.153)	(0.121)	(0.125)	(0.090)	(0.080)	(0.191)	(0.167)	(0.124)
2007	0.588***	-0.122	-0.086	0.534**	-0.152	-0.096	0.538***	-0.299**	-0.219**	0.466**	-0.233	-0.195
	(0.179)	(0.124)	(0.113)	(0.252)	(0.189)	(0.156)	(0.167)	(0.123)	(0.105)	(0.238)	(0.214)	(0.160)
2011	0.508**	-0.162	-0.157	0.443	-0.190	-0.171	0.454**	-0.354**	-0.301**	0.371	-0.273	-0.271
	(0.207)	(0.140)	(0.122)	(0.285)	(0.226)	(0.181)	(0.197)	(0.151)	(0.124)	(0.267)	(0.259)	(0.188)
Food exports	1.180	-0.758	-0.220	1.363*	-0.892	-0.078	1.069	-1.152	-0.516	1.117	-1.241	-0.482
	(0.837)	(0.973)	(0.741)	(0.828)	(1.036)	(0.789)	(0.759)	(0.887)	(0.652)	(0.731)	(0.890)	(0.649)
Fuel exports	-0.281	-0.942	-0.222	-0.198	-0.991	-0.205	-0.262	-0.872	-0.170	-0.185	-0.982	-0.193
	(0.363)	(0.657)	(0.288)	(0.341)	(0.650)	(0.306)	(0.368)	(0.677)	(0.279)	(0.343)	(0.664)	(0.304)
Urbanization	0.195	0.575	0.151	0.539	0.434	0.051	0.417	1.361	0.743	0.867	0.961	0.647
	(1.163)	(1.251)	(1.139)	(1.216)	(1.198)	(1.167)	(1.234)	(1.128)	(1.137)	(1.238)	(1.123)	(1.190)
Polity IV	-0.015	0.007	0.005	-0.018*	0.005	0.006	-0.015	0.009	0.007	-0.018*	0.004	0.006
	(0.011)	(0.007)	(0.007)	(0.011)	(0.007)	(0.008)	(0.011)	(0.006)	(0.006)	(0.011)	(0.006)	(0.007)
Fossil rents	-2.646**	0.535	-0.407	-2.326*	0.386	-0.402	-2.535**	0.929	-0.110	-2.227*	0.477	-0.242
	(1.037)	(0.944)	(0.775)	(1.215)	(1.067)	(0.816)	(0.988)	(0.996)	(0.738)	(1.139)	(1.101)	(0.760)
HDI middle	0.065	0.015	-0.024	0.113	-0.010	-0.009	0.098	0.133	0.065	0.171	0.077	0.092
	(0.430)	(0.185)	(0.218)	(0.443)	(0.184)	(0.224)	(0.415)	(0.156)	(0.204)	(0.423)	(0.160)	(0.211)
HDI high	0.178	0.097	0.119	0.263	0.042	0.148	0.209	0.209	0.203	0.310	0.117	0.229
	(0.456)	(0.233)	(0.248)	(0.468)	(0.230)	(0.257)	(0.441)	(0.210)	(0.239)	(0.451)	(0.220)	(0.253)
HDI very high	0.311	0.041	0.113	0.419	-0.037	0.141	0.331	0.113	0.168	0.444	0.008	0.183
	(0.488)	(0.234)	(0.257)	(0.489)	(0.235)	(0.266)	(0.481)	(0.227)	(0.254)	(0.478)	(0.240)	(0.269)
Hansen-J (p)	-	-	-	0.312	0.357	0.286	-	-	-	0.303	0.336	0.252
Turning point (log)	-	10.226	11.434	-	-	10.807	-	-	-	-	-	-
Turning point	-	27 620	92 411	-	-	49 387	-	-	-	-	-	-
R^2	0.390	0.203	0.281	-	-	-	0.389	0.164	0.255	-	-	-
R^2 within	-	-	-	0.379	0.193	0.275	-	-	-	0.383	0.147	0.255
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.10: FE and IV-FE results for the manufacturing sector. Note: R^2 within stands for R^2 within country.

	(1) FE			(2) IV-FE			(3) FE			(4) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	-8.718***	-0.786	-0.492	-3.068	0.095	0.408	0.296	0.141	0.165	-0.348	0.042	0.036
	(3.121)	(1.407)	(1.416)	(4.233)	(1.763)	(1.699)	(0.373)	(0.252)	(0.248)	(0.725)	(0.363)	(0.344)
ln(Income), squared	0.523***	0.054	0.038	0.158	-0.003	-0.022						
	(0.179)	(0.079)	(0.079)	(0.244)	(0.102)	(0.097)						
Annex I	0.374*	0.089	0.087	1.034	0.279	0.238	0.459**	0.098	0.093	1.124*	0.277	0.227
	(0.205)	(0.077)	(0.076)	(0.654)	(0.187)	(0.177)	(0.222)	(0.079)	(0.077)	(0.606)	(0.175)	(0.163)
Openness	-0.236	-0.033	-0.055	-0.293	-0.029	-0.064	-0.304	-0.040	-0.060	-0.304	-0.029	-0.061
	(0.310)	(0.160)	(0.179)	(0.344)	(0.151)	(0.175)	(0.358)	(0.163)	(0.180)	(0.366)	(0.151)	(0.172)
ln(Pop. density)	1.602	-0.364	-0.465	1.881	-0.147	-0.330	0.910	-0.435	-0.515	1.769	-0.143	-0.308
	(1.026)	(0.439)	(0.448)	(1.354)	(0.495)	(0.480)	(1.019)	(0.415)	(0.424)	(1.361)	(0.478)	(0.463)
2001	-0.460*	-0.016	-0.017	-0.399	-0.020	-0.011	-0.314	-0.001	-0.006	-0.365	-0.021	-0.016
	(0.245)	(0.051)	(0.050)	(0.257)	(0.064)	(0.060)	(0.220)	(0.047)	(0.046)	(0.269)	(0.060)	(0.057)
2004	-0.911**	0.164	0.162	-1.018*	0.080	0.112	-0.658*	0.190*	0.181*	-0.985*	0.079	0.106
	(0.381)	(0.100)	(0.100)	(0.552)	(0.156)	(0.147)	(0.331)	(0.097)	(0.097)	(0.574)	(0.153)	(0.145)
2007	-1.209**	0.198	0.198	-1.198*	0.124	0.168	-0.802**	0.240*	0.227	-1.126	0.122	0.156
	(0.488)	(0.145)	(0.146)	(0.667)	(0.218)	(0.206)	(0.399)	(0.141)	(0.141)	(0.695)	(0.211)	(0.199)
2011	-1.179**	0.151	0.147	-1.186*	0.065	0.112	-0.739*	0.196	0.179	-1.112	0.063	0.099
	(0.453)	(0.177)	(0.179)	(0.691)	(0.263)	(0.249)	(0.372)	(0.174)	(0.175)	(0.725)	(0.256)	(0.241)
Food exports	-0.211	0.345	0.413	0.569	0.513	0.547	0.695	0.438	0.479	0.883	0.506	0.511
	(1.329)	(0.768)	(0.770)	(1.362)	(0.831)	(0.814)	(1.365)	(0.760)	(0.765)	(1.384)	(0.796)	(0.788)
Fuel exports	0.484	-0.605*	-0.511	0.643	-0.530	-0.461	0.325	-0.621*	-0.523	0.625	-0.531	-0.458
	(1.050)	(0.360)	(0.330)	(1.072)	(0.367)	(0.342)	(1.078)	(0.366)	(0.332)	(1.085)	(0.367)	(0.340)
Urbanization	4.185	1.680	1.806	4.528	1.944	1.966	2.378	1.494	1.674	4.122	1.947	2.018
	(2.559)	(1.288)	(1.278)	(3.143)	(1.488)	(1.461)	(2.474)	(1.261)	(1.255)	(3.404)	(1.490)	(1.460)
Polity IV	0.032	0.004	0.004	0.030	0.000	0.001	0.028	0.004	0.004	0.029	0.000	0.001
	(0.028)	(0.011)	(0.010)	(0.022)	(0.009)	(0.009)	(0.028)	(0.011)	(0.010)	(0.022)	(0.009)	(0.009)
Fossil rents	0.877	-0.341	-0.358	1.656	0.016	-0.100	-0.030	-0.435	-0.424	1.523	0.019	-0.081
	(1.897)	(0.721)	(0.718)	(2.487)	(0.753)	(0.742)	(2.113)	(0.708)	(0.706)	(2.641)	(0.745)	(0.736)
HDI middle	0.885*	0.194*	0.202*	1.000**	0.228**	0.232**	0.615	0.166*	0.183*	0.936**	0.229**	0.241**
	(0.474)	(0.107)	(0.107)	(0.479)	(0.108)	(0.107)	(0.385)	(0.096)	(0.097)	(0.470)	(0.102)	(0.103)
HDI high	1.353**	0.296**	0.314**	1.641***	0.373**	0.385***	1.096**	0.270**	0.296**	1.592**	0.374***	0.392***
	(0.573)	(0.142)	(0.140)	(0.628)	(0.147)	(0.145)	(0.491)	(0.134)	(0.132)	(0.626)	(0.144)	(0.143)
HDI very high	1.443**	0.235	0.249	1.793**	0.302	0.313*	1.276**	0.218	0.237	1.764**	0.302	0.316*
	(0.663)	(0.180)	(0.173)	(0.718)	(0.188)	(0.178)	(0.608)	(0.175)	(0.167)	(0.714)	(0.188)	(0.178)
Hansen-J (p)	-	-	-	0.741	0.210	0.219	-	-	-	0.711	0.210	0.218
Turning point (log)	8.335	-	-	-	-	-	-	-	-	-	-	-
Turning point	4 169	-	-	-	-	-	-	-	-	-	-	-
R^2	0.083	0.325	0.329	-	-	-	0.058	0.322	0.328	-	-	-
R^2 within	-	-	-	0.038	0.295	0.307	-	-	-	0.019	0.296	0.310
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.11: FE and IV-FE results for the service sector. Note: R^2 within stands for R^2 within country.

		(1) FE			(2) IV-FE			(3) FE			(4) IV-FE	
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	15.602**	2.631	3.103	17.446**	5.169	5.064	1.812**	0.811**	1.067***	1.983*	1.029**	1.201**
	(6.478)	(3.873)	(3.605)	(8.095)	(4.314)	(3.970)	(0.817)	(0.360)	(0.345)	(1.057)	(0.503)	(0.523)
ln(Income), squared	-0.800**	-0.106	-0.118	-0.910**	-0.238	-0.221						
	(0.356)	(0.208)	(0.194)	(0.451)	(0.232)	(0.213)						
Annex I	-0.132	0.280***	0.319***	-0.739	0.665**	0.708***	-0.262	0.263**	0.300***	-1.197**	0.544**	0.598***
	(0.172)	(0.101)	(0.101)	(0.612)	(0.315)	(0.256)	(0.202)	(0.101)	(0.099)	(0.567)	(0.271)	(0.222)
Openness	0.356	0.072	-0.024	0.366	0.092	-0.027	0.459	0.086	-0.009	0.511	0.094	-0.036
	(0.347)	(0.169)	(0.190)	(0.384)	(0.163)	(0.170)	(0.374)	(0.192)	(0.212)	(0.386)	(0.201)	(0.208)
ln(Pop. density)	-0.185	-0.080	-0.141	-1.012	0.397	0.303	0.874	0.059	0.016	-0.081	0.517	0.417
	(1.218)	(0.662)	(0.590)	(1.561)	(0.848)	(0.714)	(1.456)	(0.805)	(0.695)	(1.750)	(0.929)	(0.773)
2001	-0.520***	0.072	0.101*	-0.424**	0.025	0.052	-0.745***	0.043	0.068	-0.659***	-0.019	0.012
	(0.176)	(0.060)	(0.059)	(0.195)	(0.088)	(0.083)	(0.226)	(0.081)	(0.072)	(0.239)	(0.108)	(0.095)
2004	-0.454*	0.203*	0.152	0.003	-0.033	-0.082	-0.840***	0.152	0.095	-0.279	-0.080	-0.125
	(0.265)	(0.105)	(0.105)	(0.393)	(0.202)	(0.195)	(0.284)	(0.112)	(0.105)	(0.467)	(0.209)	(0.193)
2007	-0.466	0.159	0.059	0.089	-0.098	-0.191	-1.088***	0.077	-0.033	-0.460	-0.203	-0.288
	(0.347)	(0.144)	(0.146)	(0.490)	(0.261)	(0.263)	(0.399)	(0.164)	(0.154)	(0.609)	(0.283)	(0.264)
2011	-0.406	0.212	0.092	0.232	-0.095	-0.203	-1.079**	0.124	-0.007	-0.347	-0.204	-0.304
	(0.378)	(0.175)	(0.172)	(0.568)	(0.315)	(0.317)	(0.455)	(0.195)	(0.178)	(0.712)	(0.331)	(0.312)
Food exports	0.584	0.031	0.218	0.350	0.550	0.606	-0.802	-0.152	0.014	-1.418	0.206	0.341
	(1.799)	(1.415)	(1.122)	(1.961)	(1.513)	(1.279)	(1.955)	(1.452)	(1.181)	(1.965)	(1.453)	(1.224)
Fuel exports	0.702	-1.905**	-0.865*	0.192	-1.715**	-0.657	0.946	-1.873**	-0.829*	0.372	-1.693**	-0.636
	(0.809)	(0.910)	(0.504)	(0.788)	(0.857)	(0.489)	(0.760)	(0.891)	(0.479)	(0.745)	(0.833)	(0.450)
Urbanization	1.083	0.974	0.518	-0.772	1.322	1.013	3.848	1.338	0.926	1.400	2.058	1.702
	(3.625)	(2.199)	(2.121)	(3.942)	(2.306)	(2.321)	(3.573)	(1.853)	(1.845)	(4.115)	(2.075)	(2.114)
Polity IV	-0.026	-0.021	-0.013	-0.037*	-0.016	-0.005	-0.021	-0.020	-0.012	-0.032*	-0.018	-0.006
	(0.020)	(0.014)	(0.011)	(0.021)	(0.015)	(0.012)	(0.016)	(0.013)	(0.010)	(0.018)	(0.014)	(0.011)
Fossil rents	-1.286	-1.606	-2.024	-2.949	-1.000	-1.415	0.101	-1.423	-1.819	-1.830	-0.925	-1.355
	(2.220)	(1.545)	(1.437)	(2.506)	(1.735)	(1.574)	(2.173)	(1.582)	(1.443)	(2.467)	(1.664)	(1.476)
HDI middle	-0.238	0.109	0.366	-0.479	0.104	0.348	0.175	0.163	0.427	-0.150	0.231	0.476
	(0.679)	(0.379)	(0.363)	(0.652)	(0.392)	(0.372)	(0.585)	(0.332)	(0.319)	(0.553)	(0.354)	(0.332)
HDI high	-0.402	0.096	0.414	-0.742	0.128	0.435	-0.009	0.148	0.472	-0.517	0.243	0.555
	(0.777)	(0.434)	(0.408)	(0.760)	(0.446)	(0.416)	(0.699)	(0.383)	(0.364)	(0.717)	(0.417)	(0.387)
HDI very high	-0.574	0.180	0.432	-0.915	0.220	0.461	-0.319	0.214	0.470	-0.832	0.296	0.548
	(0.843)	(0.444)	(0.414)	(0.844)	(0.460)	(0.419)	(0.813)	(0.413)	(0.386)	(0.835)	(0.450)	(0.403)
Hansen-J (p)	-	-	-	0.351	0.173	0.177	-	-	-	0.419	0.159	0.157
Turning point (log)	9.752	-	-	9.585	-	-	-	-	-	-	-	-
Turning point	17 180	-	-	14 551	-	-	-	-	-	-	-	-
R^2	0.239	0.355	0.382	-	-	-	0.175	0.351	0.377	-	-	-
R^2 within	-	-	-	0.207	0.313	0.336	-	-	-	0.104	0.329	0.349
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.12: FE and IV-FE results for the transport sector. Note: R^2 within stands for R^2 within country.

	(1) FE			(2) IV-FE			(3) FE			(4) IV-FE		
	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.	prod.	fin.prod.	cons.
ln(Income)	0.880	0.404	0.481	0.357	-0.228	-0.314	0.301**	0.269***	0.241**	0.334**	0.311***	0.272**
	(0.830)	(0.858)	(0.844)	(1.092)	(1.187)	(1.203)	(0.124)	(0.089)	(0.116)	(0.149)	(0.102)	(0.121)
ln(Income), squared	-0.034	-0.008	-0.014	-0.001	0.031	0.034						
	(0.048)	(0.050)	(0.050)	(0.066)	(0.072)	(0.072)						
Annex I	-0.138***	-0.047	-0.090*	-0.375***	-0.218*	-0.318**	-0.144***	-0.048	-0.093	-0.377***	-0.203*	-0.303**
	(0.047)	(0.044)	(0.053)	(0.120)	(0.119)	(0.152)	(0.049)	(0.047)	(0.056)	(0.115)	(0.118)	(0.145)
Openness	0.041	0.120	0.107	0.028	0.119	0.105	0.045	0.121	0.108	0.028	0.116	0.101
	(0.065)	(0.105)	(0.100)	(0.062)	(0.120)	(0.120)	(0.066)	(0.101)	(0.096)	(0.058)	(0.121)	(0.120)
ln(Pop. density)	-0.197	-0.100	-0.216	-0.599	-0.272	-0.469	-0.153	-0.089	-0.197	-0.598	-0.298	-0.500
	(0.370)	(0.308)	(0.318)	(0.403)	(0.381)	(0.404)	(0.325)	(0.267)	(0.280)	(0.382)	(0.351)	(0.383)
2001	-0.019	-0.004	0.029	0.012	0.012	0.058	-0.029	-0.006	0.025	0.012	0.019	0.066
	(0.029)	(0.035)	(0.051)	(0.035)	(0.041)	(0.056)	(0.024)	(0.028)	(0.045)	(0.030)	(0.032)	(0.052)
2004	0.011	-0.006	0.048	0.153*	0.077	0.171	-0.006	-0.009	0.041	0.153*	0.085	0.181
	(0.059)	(0.058)	(0.082)	(0.087)	(0.091)	(0.121)	(0.048)	(0.044)	(0.071)	(0.083)	(0.083)	(0.119)
2007	-0.028	-0.073	-0.011	0.126	0.011	0.119	-0.054	-0.079	-0.021	0.126	0.027	0.137
	(0.083)	(0.084)	(0.110)	(0.113)	(0.121)	(0.150)	(0.066)	(0.061)	(0.091)	(0.103)	(0.101)	(0.142)
2011	-0.053	-0.105	-0.034	0.128	-0.009	0.115	-0.082	-0.111	-0.046	0.129	0.008	0.134
	(0.107)	(0.098)	(0.126)	(0.141)	(0.140)	(0.174)	(0.088)	(0.070)	(0.103)	(0.132)	(0.119)	(0.165)
Food exports	0.389	0.970***	1.000***	0.212	0.891**	0.882**	0.331	0.956***	0.976***	0.204	0.949***	0.947**
	(0.261)	(0.335)	(0.357)	(0.269)	(0.367)	(0.401)	(0.254)	(0.336)	(0.355)	(0.253)	(0.356)	(0.386)
Fuel exports	-0.146	-0.011	-0.012	-0.194	-0.061	-0.091	-0.136	-0.008	-0.008	-0.195	-0.064	-0.094
	(0.171)	(0.133)	(0.142)	(0.157)	(0.147)	(0.161)	(0.175)	(0.136)	(0.144)	(0.160)	(0.146)	(0.162)
Urbanization	-0.933	0.624	0.565	-1.302*	0.387	0.211	-0.817	0.651	0.613	-1.304*	0.312	0.127
	(0.760)	(0.746)	(0.782)	(0.737)	(0.795)	(0.848)	(0.769)	(0.703)	(0.736)	(0.746)	(0.745)	(0.821)
Polity IV	0.009**	0.010**	0.010**	0.006*	0.005	0.005	0.009**	0.010**	0.010**	0.006*	0.005	0.005
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Fossil rents	-0.705	-0.552	-0.368	-0.937	-0.781	-0.672	-0.646	-0.538	-0.344	-0.937	-0.797	-0.691
	(0.739)	(0.649)	(0.668)	(0.722)	(0.672)	(0.675)	(0.747)	(0.673)	(0.693)	(0.747)	(0.701)	(0.708)
HDI middle	0.015	0.020	0.020	-0.029	-0.000	-0.009	0.033	0.024	0.028	-0.030	-0.015	-0.025
	(0.038)	(0.069)	(0.073)	(0.042)	(0.060)	(0.064)	(0.040)	(0.069)	(0.072)	(0.047)	(0.064)	(0.069)
HDI high	0.122	0.094	0.085	0.029	0.042	0.013	0.139**	0.098	0.092	0.028	0.029	-0.001
	(0.074)	(0.089)	(0.094)	(0.081)	(0.083)	(0.095)	(0.068)	(0.086)	(0.090)	(0.084)	(0.085)	(0.098)
HDI very high	0.220**	0.178*	0.179*	0.111	0.093	0.078	0.231**	0.180*	0.183*	0.109	0.087	0.071
	(0.089)	(0.103)	(0.105)	(0.098)	(0.097)	(0.104)	(0.088)	(0.102)	(0.104)	(0.100)	(0.098)	(0.105)
Hansen-J (p)	-	-	-	0.229	0.201	0.208	-	-	-	0.230	0.205	0.213
R^2	0.246	0.191	0.148	-	-	-	0.242	0.191	0.148	-	-	-
R^2 within country	-	-	-	0.093	0.109	0.053	-	-	-	0.091	0.123	0.065
N	390	390	390	390	390	390	390	390	390	390	390	390

Table C.13: FE and IV-FE results for the government administration sector. Note: R^2 within stands for R^2 within country.